

Appendix C – Letters and Other Documentation of Site-Specific Determinations by Ecology

C.1 Introduction

The purpose of this appendix is to document the letters and other documentation of site-specific determinations that have been provided by the Department of Ecology.

This appendix contains letters and other documentation organized as follows:

- C.2 Arsenic and Lead Soil Cleanup and Remediation Levels
 - C.2.1 Cleanup Levels and Remediation Levels for the Former DuPont Works Site
 - C.2.2 Residential Soil-Lead Cleanup Level and Remediation Level for Former DuPont Works Site
 - C.2.3 Non-Residential Remediation Levels at the Former DuPont Works Site
 - C.2.4 Soil Arsenic Non-Residential Remediation Levels
 - C.2.5 Arsenic in Soil – Area Background Levels
- C.3 DNT Soil Cleanup Level Protective of Groundwater
- C.4 Mercury Cleanup Levels Summary and Mercury/Lead Leaching Study
- C.5 TNT Soil Cleanup Level Protective of Groundwater
- C.6 TPH Soil Cleanup Level Protective of Groundwater
 - C.6.1 Review of TPH Soil Cleanup Level Protective of Groundwater
 - C.6.2 TPH/PAH Cleanup Level Summary

C.2 Arsenic and Lead Soil Cleanup and Remediation Levels

C.2.1 Cleanup Levels and Remediation Levels for the Former DuPont Works Site



STATE OF WASHINGTON
DEPARTMENT OF ECOLOGY

P.O. Box 47775 • Olympia, Washington 98504-7775 • (360) 407-6300

April 21, 2000

Dennis Clark
DuPont City Hall
303 Barksdale
DuPont WA 98327

Hello Dennis,

Re: Cleanup Standards and Remediation Levels for the Former DuPont Works Site

Thank you for spending time with me yesterday talking about land use and the cleanup site. I have enclosed a copy of three letters from Ecology to Weyerhaeuser and DuPont companies, per our discussion. The City of DuPont (former Mayor Shenkel) had received copies of these letters in the past.

Letter #1 (10/1/97) establishes a soil-lead cleanup standard for residential property at 450 parts per million (ppm). This cleanup standard is specific for the DuPont site and was developed using an EPA risk and exposure model and site-specific information. This cleanup standard was developed back when residential development was still being considered within Parcel 1.

Letter #2 (5/3/99) establishes soil-lead remediation levels for 4 different land use types:

- 1) golf course – 4,100 ppm
- 2) commercial – 2,100 ppm
- 3) Industrial – 1,000 ppm
- 4) Open space – 1,500 ppm

These remediation levels were developed using an EPA risk exposure model. The first three are based on adult worker exposure assumptions and the open space land use is based on an older child (7 to 18 years of age) exposure assumption. The soil-lead cleanup standard is still 450 ppm. That does not change. Any location where contaminants are left behind above the cleanup standard must be addressed through engineering and/or institutional controls, which includes deed restrictions.

Letter #3 (6/25/99) establishes soil-arsenic remediation levels for 3 different land use types:

- 1) golf course – 530 ppm
- 2) commercial – 60 ppm
- 3) industrial – 90 ppm
- 4) open space – to be determined

These remediation levels were developed using the standard Model Toxics Control Act risk formula and making adjustments to the exposure frequency parameter. Like the soil-lead remediation levels, the first three are for adult workers and the open space will be based on the older child exposure assumption. The open space soil-arsenic remediation level will probably be set at 32 ppm, the same average concentration identified in the twenty background soil samples collected outside the cleanup site boundary many years

ago. The cleanup standard for soil-arsenic is 20 ppm, based on the Model Toxics Control Act Method A number. The likely source of the elevated area-wide arsenic concentrations is the former ASARCO smelter in Ruston.

If you have any questions about the enclosed letters or want more detail on how the numbers (remediation levels and cleanup standards) were developed, please give me a call and I will provide you with that information.

On another subject, yesterday we discussed the City's year 2000 comprehensive land use plan being developed and the proposed location of future residential development. You were aware of the existing deed restrictions covering Parcels 1 and 2 of the cleanup site, which precludes residential development, now and into the future. You mentioned that conditions might change allowing for residential development within the cleanup site. Those changes included further cleanup might be conducted in the future, Weyerhaeuser might change its mind on the restrictive covenant, new technologies might be developed for easier and cheaper cleanups, etc. While I heard what you were saying yesterday, I am not sure that identifying deed restricted property for future residential development is a wise decision. The companies (Weyerhaeuser and DuPont) have stated to me, numerous times, that they have no intention of ever allowing residences within the cleanup site due to long-term liability concerns. If you need additional copies of the restrictive covenants, let me know. A copy was provided most recently to former Mayor Shenkel in a letter dated 11/15/99. They are also on file with the Pierce County Assessor's office.

One last item. Sometime in the not too distant future, I would like to set up a meeting with you and Mayor Krill and whoever else is necessary from the City and Ecology (and the companies if appropriate) to discuss the DuPont Works Environmental Impact Statement before the final version is released. Before having the meeting, I need more time to go through all the comments Ecology received on the draft and determine how we will address them. The responses to the comments will be contained in a Responsiveness Summary. I am hoping that the final EIS will be ready for release in about 6 weeks.

If you have any questions about this letter or the enclosures, please give me a telephone call at (360) 407-6262. I understand that City Hall staff are now "on line". I can also be contacted at the following e-mail address mblu461@ecy.wa.gov.

Sincerely,

Mike Blum

Mike Blum
Toxics Cleanup Program
Southwest Regional Office

Enclosures (3)

cc: Judy Krill, City of DuPont
Jim Odendahl, Weyerhaeuser Co
Jeff King, West Shores Corp.
Ron Buchanan, DuPont Co.
David Brentlinger, Weyerhaeuser Real Estate Co.
Ecology's Weyerhaeuser DuPont Project Team
Sue Mauermann, Ecology Regional

C.2.2 Residential Soil-Lead Cleanup Level and Remediation Level for Former DuPont Works Site



STATE OF WASHINGTON
DEPARTMENT OF ECOLOGY

P.O. Box 47775 • Olympia, Washington 98504-7775 • (360) 407-6300

October 1, 1997

Mr. Vern Moore
Weyerhaeuser Company
PO Box 100
DuPont, WA 98327-0100

Mr. Jack Frazier
The DuPont Company
Barley Mill Plaza Bldg. 27-1162
PO Box 80027
Wilmington, DE 19880-0027

Re: Residential Soil-Lead Cleanup Standard for Former DuPont Works Site

Dear Vern and Jack:

This letter is in reply to Tim Bingman's August 25, 1997, letter to me regarding site-specific inputs to the Integrated Exposure Uptake BioKinetic (IEUBK) model for determining residential soil-lead cleanup levels. I will also summarize our recent discussions about soil-lead cleanup in the future residential areas of the former DuPont Works Site and provide you with a decision regarding a site-specific soil cleanup standard for lead. As you know, Ecology is adopting the use of the Environmental Protection Agency's IEUBK model as a basis for setting site-specific residential cleanup levels for the protection of children. The Model Toxics Control Act (MTCA) Science Advisory Board has also concurred in the use of the model for making site-specific decisions.

Over the past several years, the Ecology Team has reviewed numerous submissions from Weyerhaeuser and DuPont Companies related to the topic of soil-lead cleanup standards, most of which dealt with the development of site-specific inputs into the IEUBK model. The most recent discussions on this topic have dealt with the soil-to-dust transfer coefficient input to the model. The standard default value for the soil-to-dust transfer coefficient is seventy percent (70%). We all agreed that 70% may not be a reasonable value to use for the Site, however, we needed adequate site-specific justification to change the default value.

Ecology used the services of Dr. Terri Bowers of Gradient Corporation to review the current literature for information that could provide a value for the soil-to-dust transfer coefficient that would be appropriate for the former DuPont Works Site. Terri provided Ecology with a report dated February 12, 1997 entitled Estimating the Soil-to-Dust Transfer Coefficient, and a memo regarding the Review of Leadville and Sandy Soil-to-Dust Relationships, dated June 24, 1997. On July 11, 1997, after initial review by the Ecology Team, I sent those same materials to Dr. Greg Glass for peer review. Greg is knowledgeable about risk assessment and has familiarity with the issue of soil-to-dust transfer at other cleanup sites. Greg responded on August 12, 1997, to my July 11 letter, which included a list of questions needing his response.

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Based on the work by Terri and Greg, it appears that the 70% default value for the soil-to-dust transfer coefficient is an overestimate for this parameter at the former DuPont Works Site. This conclusion is mostly based on the fact that 1) the new homes to be constructed at the Site will not contain lead-based paint, 2) leaded gasoline will not be used in motor vehicles in the future, and 3) the future roads in the area will not have been impacted by past leaded gasoline use. Both consultants provided similar ranges of soil-to-dust transfer coefficients that would be defensible for use at the Site.

As noted in Tim's letter, Terri recommended using a soil-to-dust transfer coefficient on the order of 15 to 45%. Greg's opinion was that the range was 15 to 50% "with relatively high confidence", or 20 to 45% "with somewhat lesser but still appreciable confidence." The Ecology Team has selected 45%, a value from the upper portion of the soil-to-dust transfer coefficient range, to account for uncertainties in the underlying data, and its application at this site. The Ecology Team then applied the 45% transfer coefficient along with a site-specific ground water lead level of 2.0 ug/l to the IEUBK model. Using these inputs, the Ecology Team determined the residential soil cleanup level that would be protective of 95% of the child population (0 to 84 months of age) at a blood-lead level of 10 ug/dl.

Using the input parameters noted above, the IEUBK model estimates a soil-lead cleanup value of 443 mg/kg as protective. The proposed future development of the residential areas of the Site includes removal of the lead-contaminated topsoil prior to home construction, followed by replacement with clean topsoil and sod after the new homes are constructed. Considering the proposed future conditions at the Site, and the accuracy of the soil-to-dust transfer coefficient estimate, Ecology approves a risk management concentration of 450 mg/kg as protective of human health in the future residential areas at the former DuPont Works Site.

The Ecology Team recognizes that agreement on this issue marks a significant milestone in the project. We look forward to resolving the remaining technical issues including a soil-lead cleanup standard for the non-residential areas of the Site. If you or any of your team have any questions regarding this letter, please give me a telephonic call at (360) 407-6262.

Sincerely,

Mike Blum

Mike Blum
Site Manager
Toxics Cleanup Program

MB:td

cc: Distribution list

Mr. Vern Moore
Mr. Jack Frazier
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cc: Tim Bingman, DuPont Company
Terri Bowers, Gradient Corporation
Mary Burg, Ecology Toxics Cleanup Program Manager
Greg Glass, Greg Glass Consulting
Mark Jobson, Assistant Attorney General
Jeff King, DuPont Company
Roseanne Lorenzana, Environmental Protection Agency
Craig McCormack, Ecology Toxics Cleanup Program
Pamela Meitner, DuPont Company Legal Department
Ralph Palumbo, Summit Law Group
Willard Shenkel, City of DuPont
Jim White, Washington State Department of Health
Marian Wineman, Woodward Clyde Consultants
Ecology's Weyerhaeuser/DuPont Site Team

C.2.3 Non-Residential Remediation Levels at the Former DuPont Works Site



STATE OF WASHINGTON
DEPARTMENT OF ECOLOGY

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May 3, 1999

Mr. Vern Moore
Weyerhaeuser Company
Post Office Box 100
DuPont, WA 98327-0100

Mr. Izzy Zanikos
DuPont Specialty Chemicals
Barley Mill Plaza Building 27
Post Office Box 80027
Wilmington, DE 19880-0027

Dear Vern and Izzy:

Re: Non-Residential Remediation Levels at the Former DuPont Works Site

The Department of Ecology (Ecology) Team working on this project has made some decisions regarding remediation levels for lead in soil at the site. These remediation levels, formerly known as action levels, are for land uses other than residential. These remediation levels are levels at which we believe there is limited threat to human health and the environment based on assumed exposure scenarios and the implementation of various institutional controls and property deed restrictions. As a reminder, remediation levels are not synonymous with cleanup levels or cleanup standards.

I received Tim Bingman's letter of December 18, 1998 on the 21st of December. That letter proposed remediation levels for lead and arsenic in soils for the future golf course, industrial, commercial, and open-space land use areas. Remediation levels for arsenic in soil will be addressed in another letter in the near future.

First let me identify the site-specific soil-lead remediation levels to be established by Ecology and then explain how we arrived at those levels. Some levels are the same or slightly higher than what you proposed, while others have been reduced based on different exposure assumptions.

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Table #1
Summary of Ecology-Derived Remediation Levels
For the Former DuPont Works Site

Future Land Use Area	Lead in Soil
Golf Course	4,100 ppm
Commercial	2,100 ppm
Industrial	1,000 ppm
Open Space	1,500 ppm

¹ Use same soil-lead remediation level as in Parcel 2 as opposed to Adult Lead model value of 1,963 ppm.

Tim Bingman and I made a presentation to the Model Toxics Control Act Science Advisory Board in November 1998 regarding the use of EPA's Adult Lead model to develop soil-lead remediation levels at cleanup sites in Washington. They gave their approval to the use of the model and the model's guidance document. As proposed in Tim's December 1998 letter, Ecology concurs with the use of the region-specific baseline blood-lead level (Washington State) and blood-lead geometric standard deviation (Western U.S.); 1.36 micrograms per deciliter (ug/dl) and 1.81, respectively. Table #2 below outlines the specific input parameters to the Adult Lead Model equation and the values selected by Ecology as appropriate for the former DuPont Works site.

Table #2 - Adult Lead Model Input Variables

Description of Input Variables	Equation Variables	Units	Commercial Exposure Scenario	Golf Course Exposure Scenario	Industrial Exposure Scenario
95 th Percentile PbB (Blood Lead) in Fetus	PbB _{fetal,0.95}	ug/dl	10	10	10
Fetal/Maternal PbB Ratio	R _{fetal/maternal}	----	0.9	0.9	0.9
Biokinetic Slope Factor	BKSF	ug/dl per ug/day	0.4	0.4	0.4
Geometric Standard Deviation PbB	GSD _{i,adult}	----	1.81	1.81	1.81
Baseline PbB	PbB _{ndult,0}	ug/dl	1.36	1.36	1.36
Soil Ingestion Rate	IRs	g/day	0.200	0.100	0.050
Absorption Fraction	AFs	----	0.12	0.12	0.12
Exposure Frequency	EF	days/year	52	52	219
Averaging Time	AT	days/year	365	365	365
Remediation Levels	PbS	mg/kg	2,067	4,134	1,963

(The values in **bold** are different from those proposed by Weyerhaeuser and DuPont)

The Ecology Team considered the input variables proposed by the companies. The choice of input variables is a risk management decision and is based on best professional

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judgement, unless of course site-specific data is available. We decided that the above variables should be used for the following reasons:

1. The golf course cap is an engineered containment facility. As such, greater controls, both physical and institutional, can and will be implemented.
2. The commercial areas worked in by landscapers may not have the same protective measures as the golf course, nor will workers necessarily be aware that the areas they are working in are part of a hazardous waste site with possible residual soil contamination. Draft EPA Region 10 guidance recommends 200 mg/day as an adult soil ingestion rate for occupational exposures involving soil contact activities. The golf course worker will be better informed about the site being a hazardous waste containment facility, and as such, will be required to take better precautions to reduce exposure to (ingestion of) contaminated soils, as compared to commercial area landscape workers. That is why we have chosen 100 mg/day as the appropriate ingestion rate for the golf course worker versus the 200 mg/day recommended by EPA. To further reduce exposures, the companies have stated that the irrigation lines at the golf course will be located either in clean backfill or above the contaminated soil layer. This can be ensured through course design, which will occur with Ecology oversight.
3. The frequency of contact for the industrial land use scenario was changed to match the default value in the Adult Lead Model. The 40% value (146 days) from the Model Toxics Control Act soil/carcinogen risk formula is not appropriate for use in this model.
4. The exposure frequency for the golf course worker is set at 52 days per year. As noted in Tim's letter and the attached appendices, the Ecology Team agrees that an appropriate estimate for the exposure frequency is 36 days per year (possibly even less, depending upon site layout and engineering controls), however a minimum value of 52 days per year must be used to avoid "violating" the adult lead model assumptions (steady-state blood lead levels).
5. The industrial land use remediation level has been reduced from 1,963 to 1,000 ppm to match the Model Toxics Control Act Method A industrial cleanup value established for Parcel #2 in the 1997 Cleanup Action Plan, as recommended by the companies.
6. The Adult Lead Model is set to be protective of the fetus of a pregnant woman, the most susceptible sub-population. To be protective of an adult (non-pregnant worker), the remediation levels for each land use scenario would be considerably higher. The target blood lead level of 10 ug/dl was established to be protective of the fetus as well as very young children.

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Next let me describe how the Ecology Team selected 1,500 ppm as the soil-lead remediation level for open space areas. The companies proposed a ratio approach based on using the results of the site-specific residential cleanup levels established for the site - 450 ppm. That level was determined using EPA's Integrated Exposure Uptake Biokinetic (IEUBK) Model and is based on young children up to 84 months old. The most frequently exposed population in the open space areas, which are the natural areas and not developed parks or ball fields, would most frequently be the "older child". The older child is somewhere between 7 and 18 years of age. There is no specific age at which the older child's biokinetics responds similarly to an adult, especially in terms of absorption of lead. Most researchers agree that the younger child absorbs lead more readily than the older child or the adult. So, how does one develop a remediation level when no soil-lead exposure model exists for the older child? As noted above, the companies proposed an "exposure ratioing" approach that results in a remediation level of 3,159 ppm. That level is based on a once a week exposure compared to daily exposure at the residential cleanup level of 450 ppm. $[(7 \text{ days/week} \div 1 \text{ day/week}) * (450 \text{ ppm}) = 3,150 \text{ ppm}]$ (The difference between Ecology's (3,150 ppm) and the companies' (3,159 ppm) remediation level is the minor difference between the use of a 1 day per week ratio versus a 52 days per year ratio.) The goal of the IEUBK model is to protect 95% of the children from exceeding a blood lead level of 10 ug/dl. Exposure frequencies of 2 and 3 days per week result in remediation levels of 1575 ppm and 1050 ppm respectively.

Using the Adult Lead Model to develop remediation levels for the older child is another approach. Using the adult lead model with exposure frequencies of 1, 2, and 3 days per week results in remediation levels of 3512 ppm, 1756 ppm, and 1171 ppm respectively.

Under all scenarios, the maternal/fetal blood lead ratio was eliminated and the goal of protecting 95% of the older child population from exceeding 10 ug/dl blood lead level was retained. As a point of reference, the adult blood lead level goal ("not to exceed" value) is based on industrial exposures and is generally set at 25 to 30 ug/dl for males. The geometric standard deviation and baseline blood lead level input remained unchanged.

The two approaches yield ranges of approximately 1,050 to 3,150 ppm and 1,200 to 3,500 ppm. The site-specific residential cleanup level for lead in soil is 450 ppm. The value for open space proposed by the companies was 3,159 ppm. The upper bound is dependent on the assumed exposure scenario and the input parameters. The Ecology Team has set the soil-lead remediation level for the open space as 1,500 ppm based on consideration of the above criteria and best professional judgement regarding this risk management decision. As you know, most of the open space areas are relatively clean, with some isolated areas of elevated contaminant concentrations (e.g., hot spots). The Team carefully thought about exposure frequency and considered twice a week as appropriate, resulting in remediation levels of 1575 and 1750 ppm using the ratio approach and the adult lead model, respectively. In making this risk management decision, the Ecology Team also considered the older child transporting lead

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contamination back home on their shoes and clothes, which could create additional exposures to themselves and/or to other/younger children in the house.

One last issue. The Toxics Cleanup Program is currently in the midst of a major change to the Model Toxics Control Act. The program is also wrestling with some significant issues related to arsenic in soil. Those things will affect how we address arsenic remediation levels at the former DuPont Works site. Due to the above changes as well as ongoing discussions with the companies, the Ecology Team is addressing arsenic issues separate from lead. Site-specific arsenic remediation levels will be established in a letter that will follow in the near future.

In conclusion, the Ecology Team has spent considerable time considering your remediation levels proposal contained in Tim Bingman's December 1998 letter. We feel that the input variables chosen by Ecology are reasonable and protective. As stated earlier in this letter, we feel that the golf course cap/containment facility provides the best physical and institutional controls on future exposure to contaminated soils. As in the past, this project's cleanup Team (Weyerhaeuser, DuPont, and Ecology) is once again breaking new ground, this time with use of EPA's Adult Lead Model. These innovative approaches take more time to evaluate than following the well-worn path others have used. We are comfortable that the soil-lead remediation level decisions Ecology has made will stand up to public scrutiny, when we get to that point. There is adequate conservatism built into the assumptions used, while not being overly conservative.

If you have any questions regarding this letter or the calculations and risk management decisions regarding remediation levels, please give me a call at (360) 407-6262.

Sincerely,

Mike Blum

Mike Blum
Site Manager
Toxics Cleanup Program
Southwest Regional Office

cc: Tim Bingman, DuPont Company
Ralph Palumbo, Summit Law Group
Pamela Meitner, DuPont Company Legal Department
Mark Jobson, Assistant Attorney General
Jeff King, West Shores Corporation
Willard Shenkel, City of DuPont
Ecology's Weyerhaeuser/DuPont Site Team
David Jansen, Toxics Cleanup Program Section Supervisor

C.2.4 Arsenic Non-Residential Soil Remediation Levels



STATE OF WASHINGTON
DEPARTMENT OF ECOLOGY

P.O. Box 47775 • Olympia, Washington 98504-7775 • (360) 407-6360

June 25, 1999

Mr. Vern Moore
Weyerhaeuser Company
P.O. Box 100
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Mr. Izzy Zanikos
DuPont Specialty Chemicals
Barley Mill Plaza Building 27
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Wilmington, DE 19880-0027

Dear Vern and Izzy:

Re: Soil Arsenic Non-Residential Remediation Levels

The Department of Ecology (Ecology) Team received Tim Bingman's letter dated June 1, 1999, regarding the development of non-residential remediation levels for arsenic in soil at the former DuPont Works cleanup site. Tim's letter was received on June 2nd. The letter incorporated the issues we had discussed during our May 25, 1999, meeting at the site as well as some issues related to open space land use areas that were not discussed that day. The Ecology Team (Dan Alexanian, Kelly Susewind, and myself) is in concurrence with the proposed remediation levels with the proviso that engineering controls will be used to limit exposure to golf course workers. The assumed exposed individual based on that particular land use is the basis for the associated remediation level, which are as follows:

PROPOSED LAND USE	POTENTIALLY EXPOSED INDIVIDUAL	REMEDICATION LEVEL
Commercial	Adult landscape worker	60 milligrams per kilogram (mg/kg) or parts per million
Golf Course	Adult golf course worker	530 mg/kg
Industrial	Adult worker	90 mg/kg

I have included the specific input variables as an attachment to this letter, which I copied directly from Tim's letter.

The open space land use areas do not have a proposed soil-arsenic remediation level. A "combination of engineering solutions" was proposed in Tim's letter that includes some soil removal and some in-place capping/containment. Ecology believes that the soil-arsenic remediation goal for the open space areas should be 32 mg/kg, which is the same as the area background for the site. In working towards that goal, Ecology also wants to ensure that the net environmental benefit of any proposed action is positive. We have talked numerous times about the issue of net environmental benefit of cleanup in open space areas.

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That includes the impacts of either excavation and/or capping of contaminated soils versus leaving the contaminants in place and not disrupting the environment. Our teams have collectively reached a verbal understanding of generally what needs to occur and why. What is lacking is that reasoning written down in a more formal manner. Your request needs to be a "stand alone" document, like most of the past proposals you have submitted. When someone outside our respective team reads your request letter as well as Ecology's response, they should have a clear understanding of the issues and the reasoning behind your request and Ecology's response.

In general, as well as specifically in terms of the open space areas, a goal of Ecology and the companies is to safeguard water quality in Sequelitchew Creek, Old Fort Lake and Puget Sound. A couple protective measures includes limiting work on steep slopes and creating erosion problems as well as saving trees and habitat where possible - especially in the designated open spaces. As we have discussed, specific open space locations needing remediation will be made on a case by case basis. As discussed in Tim's letter, remediation of arsenic impacted soils along the narrow gauge railroad corridor, within the Sequelitchew Creek canyon open space area (Open Space #1), will be capped with gravel. That action will serve as both a physical barrier to exposure as well as creating part of the planned walking trail down the Sequelitchew Creek canyon to Puget Sound. Your request letter should discuss why other more permanent options are not feasible, such as excavation and off-site disposal or on-site treatment, and why those options may cause more harm than good.

I would like to point out a few things about the gravel capping approach for the narrow gauge railroad corridor mentioned in Tim's letter. There are some difficulties, or potential opportunities, depending on how one looks at it. In reviewing the existing narrow gauge sampling data within Open Space #1, it appears that there were four or five samples collected (RR-596, RR-597, RR-598, RR-599, and LR-68), all of which exceeded the area background arsenic concentration of 32 ppm. Therefore, that entire section of track would need to be covered with gravel. Tim's letter proposed a "six-inch thick layer of gravel extending five feet on either side of the railroad centerline". Why five feet? That proposal needs to be justified. The railroad corridor data from the site includes samples collected along the centerline and some samples 25 and 50 feet on either side of the centerline. Further "downstream" of Open Space #1, there were no samples collected along the narrow gauge railroad. That area is outside the consent decree boundary. When we established the boundary, it was based on soil-lead contamination. At that time, 1991, arsenic was not known to be a contaminant at the site. Do you have any information about whether that section of track was sprayed with arsenic-based herbicides in the past? I understand that there is a mitigation agreement between the City of DuPont (City) and Lone Star Northwest (Lonestar) regarding conversion of a portion of the railroad corridor to a trail along Sequelitchew Creek canyon. I have not yet seen or read that agreement, so I do not know the details. I understand that section of track/railroad corridor is to be covered with wood chips. Is there a possibility of working with the City and Lonestar to pave or gravel the entire railroad corridor down the canyon, thereby addressing both remediation concerns and gravel mining mitigation at the same time? Also, gravel would make a better (more permanent) path than wood chips.

A couple other final comments and questions. In Open Space Area #3, the buffer zone along the southern and eastern site perimeter, a 75-foot strip of vegetation will be left. Does the 75-foot border start at the fence line or the inside edge of the existing dirt road? If the existing dirt road is part of that open space, do you think vegetation will be planted or will it be naturally re-vegetated? Capping in the open space areas will reduce the exposure potential by cutting off or reducing that exposure pathway. It does not however reduce the contaminant concentration remaining, as mistakenly stated in Tim's letter.

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It is Ecology's desire to work with the companies to protect the open spaces and the ecological resources to the extent practicable. If you have any questions regarding this letter or what the Ecology Team is expecting regarding the open space areas and additional net environmental benefit evaluation, please give me a call at (360) 407-6262.

Sincerely,

Mike Blum

Mike Blum
Site Manager
Toxics Cleanup Program
Southwest Regional Office

MB:mt(1/tep)
Attachment

cc: Mark Jobson, Assistant Attorney General
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Ralph Palumbo, Summit Law Group
Willard Shenkel, City of DuPont
Ronald Summers, Lone Star Northwest
Jeff King, West Shores Corporation
Marian Wineman, Woodward Clyde
Ecology's Weyerhaeuser/DuPont Site Team
David Jansen, Ecology

Attachment #1

**Bases for Input Variables Used to Calculate
Non-Residential Arsenic Remediation Levels**

A description of the major inputs to the MTCA intake equation, as well as an explanation for values used in calculating arsenic remediation levels, is described below.

RISK – Represents the acceptable incremental carcinogenic risk level. In the case of all three land use scenarios, this value is 1×10^{-5} . The 1×10^{-5} value is codified for industrial settings in the MTCA at WAC 173-340-745 (4)(a)(iii)(B). The policy to use a value of 1×10^{-5} for the commercial areas (which is also applicable to the golf course area) was established by Pete Kmet in a memorandum dated February 14, 1995.

ABW – Describes the average body weight for the potentially exposed population under consideration. For the commercial, golf course and industrial areas, this would be an adult, with an average body weight of 70 kg.

LIFE – Represents the duration of a human lifetime over which the exposure is averaged. Per WAC 173-340-740 (3)(a)(iii)(B), the default value is 75 years.

UCF – This is a unit conversion factor of 1×10^6 applied to calculate remediation levels in units of mg/kg.

CPF – This describes the carcinogenic potency factor for arsenic. The current value for arsenic in USEPA's IRIS database is $1.5 \text{ mg/kg/day}^{-1}$.

SIR – Represents the soil ingestion rate for exposure to site soils. Ecology has recommended a value of 200 mg/day for establishing remediation levels for the future commercial land use area. A value of 100 mg/day has been recommended by Ecology for use in the golf course area, in light of the training that golf course workers receive. The 50 mg/day value is the MTCA default for industrial exposure.

AB – Represents the gastrointestinal absorption rate. DuPont and Weyerhaeuser believe that current scientific evidence supports the value of 0.4 (40%) as specified for arsenic in the MTCA "Cleanup Levels and Risk Calculation" document. However, we understand that Ecology anticipates modification of this value as a matter of policy to 100% absorption in the near future. Hence, the updated value has been used in these calculations.

DUR – Describes the duration of exposure in years. The value of 20 years for industrial exposure is the MTCA default value. The value of 20 years for the commercial and golf course areas is specified in Pete Kmet's memorandum of February 14, 1995, and is appropriate, given that adults represent the potentially exposed population.

FOC – Represents the frequency of contact term. Frequency of contact, as used in the MTCA equation, is calculated from the exposure frequency for the commercial, industrial and golf course land use scenarios. The value of 52 days/year represents a once-per-week exposure in the commercial area. The 12 days/year value for the golf course worker is based on a combination of interviews of golf course managers describing the approximate frequency for subsurface soil exposure during maintenance activities, and the anticipated use of clean backfill material around irrigation main lines at the golf course. The 40% frequency of contact for the industrial areas (corresponding to an exposure frequency of 146 days/year) is the MTCA default for industrial exposure.

C.2.5 Arsenic in Soil – Area Background levels



STATE OF WASHINGTON
 DEPARTMENT OF ECOLOGY

P.O. Box 47775 • Olympia, Washington 98504-7775 • (360) 407-6300

March 11, 1996

Mr. Vern Moore
 Weyerhaeuser Company
 P.O. Box 100
 DuPont, WA 98327-0100

Mr. Jack Frazier
 The DuPont Company
 DuPont Chemicals, B-12230
 1007 Market Street
 Wilmington, DE 19898

Dear Vern and Jack:

Re: Arsenic in Soil - Area Background Levels - 32 Parts Per Million

This letter is to confirm our recent discussions about arsenic and the area background soil concentration that has been determined for the former DuPont Works Site. The Ecology Team has reviewed the data submitted in the draft Remedial Investigation (RI) report dated December 22, 1994, as well as a separate but similar undated 6 page paper entitled Area Background Arsenic Levels, both prepared by Hart Crowser. The conclusion reached by Hart Crowser is that the area background concentration is 32 mg/kg, following the Model Toxic Control Act (MTCA) regulations and associated guidance. The Ecology Team concurs with the determination of 32 parts per millions (ppm) as the area background concentration for arsenic in soil.

So, what does that 32 ppm determination mean in terms of site cleanup decisions? Ecology will not require any soil cleanups to be more stringent than 32 ppm, irrespective of land use. Site-specific cleanup standards and action levels for arsenic in soil have not been determined for this Site. You and your consultant, Sciences International, Inc., are currently working on a proposal to reassess the toxicity of arsenic, which may affect soil-arsenic cleanup levels for this Site. As a point of reference, at this point in time, the arsenic cleanup standard for the Site would be 32 ppm for residential land use and 200 ppm for industrial land use. Cleanup standards for other land uses such as commercial, recreational, open space, etc., would fall somewhere in between 32 and 200 ppm.

It is interesting to note a couple points about natural background concentrations of arsenic in surficial soil throughout Washington State. Sampling conducted by the United States Geological Survey, under a project¹ through Ecology, found the following results:

<u>Areas of the State</u>	<u>Arsenic (GFAA² Lab Method)</u>	<u>Arsenic (ICP³ Lab Method)</u>
Puget Sound Area	7.30 mg/kg	22.80 mg/kg
Western Washington	6.37 mg/kg	46.21 mg/kg
Statewide	6.99 mg/kg	41.81 mg/kg

¹ Ecology, Natural Background Soil Metals Concentrations in Washington State October 1994, publication #94-115

² Graphite Furnace Atomic Absorption (GFAA), EPA Methods 7060 & 7740

³ Inductively Coupled Plasma (ICP) Atomic Emission Spectroscopy, EPA Methods 3050 & 6010

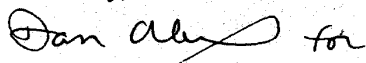
Mr. Vern Moore
Mr. Jack Frazier
March 11, 1996
Page 2

As shown above and noted in the 1994 Ecology report, using GFAA for arsenic analysis allows one to achieve lower detection limits than using ICP methods and is therefore more accurate at lower levels. ICP analysis can produce higher values for arsenic because of iron (iron acts as an interferant and is difficult to correct for when analyzing for arsenic using ICP Methods).

One last point that we all need to keep in mind. All future characterization and confirmation/verification analyses should use the same analytical methods that we have been using to date. We need to ensure all the data, past and future, is comparable. The original Quality Assurance Project Plan identified GFAA as the primary methodology for soil-metals analyses, with the exception of mercury.

If you have any questions regarding this letter and area background levels for arsenic in soil, please give me a call at (360) 407-6262.

Sincerely,



Mike Blum
Site Manager
Toxics Cleanup Program
Southwest Regional Office

MB:jr

cc: Ecology's Weyerhaeuser/DuPont Site Team
Greg Glass, Greg Glass Consulting
David Jansen, Ecology
Ed Kenney, DuPont Toxics Citizen Oversight Project
Jeff King, DuPont Environmental Remediation Services
John Kreiter, DuPont Company Legal Department
Ralph Palumbo, Heller, Ehrman, White, & McAuliffe
Willard Schenkel, City of DuPont
Tom Skjervold, DuPont Toxics Citizen Oversight Project
Steve Thiele, Assistant Attorney General
Marian Wineman, Hart Crowser, Inc.

C.3 DNT Soil Cleanup Level Protective of Groundwater



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W

STATE OF WASHINGTON
DEPARTMENT OF ECOLOGY

P.O. Box 47775 • Olympia, Washington 98504-7775 • (360) 407-6300

January 12, 1996

Mr. Vern Moore
Weyerhaeuser Company
P.O. Box 100
DuPont, WA 98327-0100

Mr. Jack Frazier
The DuPont Company
DuPont Chemicals, B-12230
1007 Market Street
Wilmington, DE 19898

Dear Vern and Jack:

Re: Acceptance of Two Issue Papers - 1) Determination of a DNT Soil Cleanup Level
Protective of Groundwater, and 2) Impracticability of Groundwater Treatment

The Ecology Team reviewed the two latest drafts of the above mentioned documents for the Former DuPont Works Site as drafted by Hart Crowser. We find them to be acceptable and agree with the conclusions contained in those issue papers. No further rewrites are necessary nor should other changes be made to them prior to their incorporation as is into the final draft remedial investigation and feasibility study reports.

The Ecology Team is still reviewing numerous other issues and/or papers submitted or raised at previous meetings. Some of those issues are listed below. Of course, this is not an exhaustive list:


- 1) The paper entitled Summary - Potential Leachability of Lead and Arsenic in Golf Course Use Areas.
- 2) The question of leachability of Bunker C in Area 8 and whether the excavations can be backfilled.
- 3) Exposure units.
- 4) Arsenic background concentrations.
- 5) Arsenic cleanup standards and Sciences International, Inc., work.
- 6) MTCA Lead cleanup standards using the IEUBK model.
- 7) Site-specific lead bioavailability study.
- 8) Statistics
- 9) Ecological risk assessment and Greg Linder's work, just to name a few.

Mr. Vern Moore
Mr. Jack Frazier
January 12, 1996
Page 2

The Ecology Team is close to finalizing or making a decision on more than half of the above mentioned items.

If you have any questions regarding this letter, please give me a call at (360) 407-6262.

Sincerely,



Mike Blum
Site Manager
Toxics Cleanup Program
Southwest Regional Office

MB:jr

cc: Ecology's Weyerhaeuser/DuPont Site Team
David Jansen, Ecology
Jeff King, DuPont Environmental Remediation Services
John Kreiter, DuPont Company Legal Department
Ralph Palumbo, Heller, Ehrman, White, & McAuliffe
Steve Thiele, Attorney General's Office
Marian Wineman, Hart Crowser, Inc.

**DETERMINATION OF A DNT SOIL CLEANUP LEVEL
PROTECTIVE OF GROUNDWATER
FORMER DUPONT WORKS SITE
DUPONT, WASHINGTON**

Conservative evaluations of Site conditions indicate that a soil cleanup level for dinitrotoluene (DNT) of 3 mg/kg provides a high level of protection to groundwater at the Former DuPont Works Site (Site), assuming a hypothetical drinking water exposure.

Soil Cleanup Level Determination

The DNT soil cleanup level for drinking water protection was calculated probabilistically using the following method with conservative input assumptions:

$$\text{soil cleanup level (mg/kg)} = \text{drinking water screening level (mg/L)} * \text{DAF (unitless)} * K_d (\text{L/kg}) \quad (1)$$

where

- ▶ the MTCA drinking water screening level for DNT is 0.00013 mg/L;
- ▶ DAF is the dilution/attenuation factor, which, for this evaluation, considered only dilution occurring as a result of natural mixing of infiltration with groundwater flow in the upper ten feet of Site aquifers; and
- ▶ K_d is the Site-specific DNT soil:water desorption coefficient determined from toxicity characteristic leaching procedure (TCLP) testing.

Equation (1) was run as a Monte Carlo simulation using Crystal Ball software, a forecasting and risk analysis add-on to Excel software. In the Monte Carlo simulation, equation (1) was solved 5,000 times using input parameter values picked randomly from probability distributions for K_d and DAF developed from Site-specific and regional information. The soil cleanup level results determined from the 5,000 iterations were compiled automatically into a probability distribution for which percentiles were generated. The 5th percentile value of that distribution represents a conservative estimate of a DNT soil cleanup level protective of Site groundwater under a hypothetical drinking water exposure scenario, i.e., there is 95 percent probability that a 3 mg/kg DNT soil cleanup level is protective of Site groundwater.

Cleanup Level Determination Assumptions

Because the DNT drinking water screening level was set as a constant in equation (1), assumptions were required only for the desorption coefficient (K_d) and DAF in determining a Site-specific soil cleanup level for DNT. The assumptions follow, and supporting information is provided in Attachment A.

Desorption Coefficient (K_d) for DNT. A Site-specific DNT soil:water desorption coefficient (K_d) was developed from TCLP results for 27 samples of Site soils. Informal discussions with the Washington State Department of Ecology (Ecology - Charles San Juan, personal communication, August 1995) indicate that TCLP is an acceptable method for obtaining desorption coefficient (K_d) estimates for organic compounds like DNT. Statistical evaluation of the K_d values indicates that they are lognormally distributed with a geometric mean of 20 L/kg and geometric standard deviation of 4.0 L/kg (see Table 1). The geometric standard deviation was decreased, such that the K_d probability distribution in the Monte Carlo simulation was constrained within the range of Site-specific values determined from TCLP testing. Without the adjustment of standard deviation, the modeled distribution projected well outside the range of measured values. The resulting K_d probability distribution extends from 2 to 190 L/kg (refer to page A-5 in Attachment A [values are in natural logs]), which encompasses all but the single lowest and single highest measured values (0.2 and 248 L/kg, respectively; see Table 1). Figure 1 provides a comparison of the modeled and measured probability distributions for K_d for DNT at the Site.

Dilution/Attenuation Factor (DAF). A dilution/attenuation factor (DAF) represents the reduction in concentration occurring during transport from the bottom of the impacted soil, through the vadose zone, to a monitoring point within the aquifer. The DAF includes dilution (e.g., mixing and dispersion) and attenuation (e.g., sorption, reaction, and degradation) occurring both in the vadose zone and in the aquifer. Consistently low DNT concentrations detected in Site monitoring wells located downgradient of areas where high DNT soil concentrations existed prior to interim source removal may suggest a large DAF for DNT at the Site.

For this evaluation, the DAF was limited to reflect only the natural dilution occurring in the upper ten feet of Site aquifers (i.e., all other dilution/attenuation processes were not considered). A ten-foot thickness of aquifer was selected as a conservative assumption based on protecting a hypothetical drinking water exposure. Groundwater discharging at the sea level seeps is not a potential drinking water source because of salinity (per WAC 173-340-720-[1][a][ii][B]; refer to Hart Crowser, 1994), and the

seeps are submerged daily by high tides. DNT was not detected in freshwater springs discharging to Sequatchew Creek in four years of monitoring. Therefore, a drinking water exposure at the Site could only occur by constructing and operating a water supply well. In practice, a well would be installed as far below the water table as practical to provide for pump clearance and well losses, and to maximize available drawdown and thus well yield. A well completed deeper in the aquifer would draw water from a greater aquifer thickness, and thus allow greater mixing to occur. Considering dilution in only the upper ten feet of aquifer, corresponding to a small (ten-foot) well penetration, provides an additional conservative assumption in developing a DAF for the Site. Because this DAF considers only physical mixing of the infiltration water with groundwater in the aquifer, and does not include any chemical attenuation processes, it is applicable for all constituents at the Site.

The dilution factor represents the ratio of the groundwater flux (through a one-foot-wide by ten-foot-thick vertical cross sectional area of aquifer) to the infiltration flux (through a one-square-foot surface area). The assumptions used in estimating the aquifer flux and infiltration flux in the Monte Carlo simulation are listed below.

Infiltration flux was calculated as follows:

$$Q_i = (P - ET - RO) * A_{\text{surface}} * (\text{foot}/12 \text{ inches}) * (7.48 \text{ gal}/\text{ft}^3) * (\text{year}/525,600 \text{ min})$$

where

Q_i = infiltration flux in gpm;

P = precipitation in inches/yr;

ET = evapotranspiration in inches/yr;

RO = runoff in inches/yr;

A_{surface} = surface area of 1 ft²; and

The last three terms on the right side of the equation are units conversion factors as indicated.

- For the Monte Carlo simulation, precipitation was assigned a triangular distribution with minimum, most likely, and maximum values of 25.6, 37.8, and 50.0 inches per year, respectively, based on annual precipitation data from the Tacoma station. The measured annual values ranged from 24.9 to 46.9 inches per year. The average (37.8 in/yr) and standard deviation (6.1 in/yr) of the annual precipitation values were calculated, and the average value was used as the most likely value in the triangular distribution. The average plus and minus two standard deviations represented the maximum and minimum values, respectively, in the distribution (see page A-5 in Attachment A).

- ▶ Evapotranspiration was assigned a uniform distribution with minimum and maximum values of 19.9 and 20.1 inches per year, respectively, based on estimated evapotranspiration values from the Tacoma (19.9 inches/yr) and Puyallup (20.1 inches/yr) stations reported in Washington State University (1968) (see page A-5 in Attachment A).
- ▶ Runoff was assigned a uniform distribution within minimum and maximum values of 0 and 5.0 inches per year (see page A-6 in Attachment A). Although regional measurements of surface runoff were not obtained (data are rarely measured), Thorthwaite and Mather (1957) suggest 10 percent of precipitation as a reasonable estimate for many soils. Because of the permeable Site soils and limited observable runoff at the Site, runoff was assumed to range from 0 in/yr (most conservative assumption) to 10 percent (reasonable upper-bound value) of the maximum precipitation value (10 percent of 50 in/yr = 5.0 in/yr).

Groundwater flux in the aquifer was calculated using Darcy's Law of the form:

$$Q_{gw} = (K * i * A_{aquifer}) * (\text{foot}/30.48 \text{ cm}) * (60 \text{ sec}/\text{min.}) * (7.48 \text{ gal}/\text{ft}^3)$$

where

Q_{gw} = flux of groundwater in gpm, within the upper 10 feet of aquifer;
 K = aquifer hydraulic conductivity in cm/sec;
 i = hydraulic gradient in ft/ft;
 $A_{aquifer}$ = aquifer vertical cross sectional area in ft^2 normal to groundwater flow; and

The last three terms on the right side of the equation are units conversion factors as indicated.

For the dilution factor to be applicable across the Site, probability distributions for hydraulic parameters were developed to represent both the Water Table Aquifer and unconfined Sea Level Aquifer at the Site.

- ▶ Hydraulic conductivity (K) was assigned a lognormal distribution with geometric mean of 5×10^{-2} cm/sec and a standard deviation of 25 percent of the mean. The mean value provides a reasonable conservative estimate for representing both Site aquifers based on available data (Hart Crowser, 1994). Because the aquifer dilution factor will be most sensitive to uncertainty in K , a standard deviation of 25 percent of the mean value was selected to provide a relatively constrained, thus useful, range of groundwater fluxes while encompassing the reasonable range of expected values for K in both

Site aquifers (5×10^{-3} to 5×10^{-1} cm/sec; refer to page A-6 in Attachment A [values are in natural logs]).

- ▶ Hydraulic gradient (i) was assigned a triangular distribution with minimum, most likely, and maximum values of 0.005, 0.028 (midpoint of range), and 0.05 ft/ft, respectively. The range of gradient values encompasses values measured in both Site aquifers (Hart Crowser, 1994).
- ▶ Aquifer cross sectional area was set at 10 ft², which is a one-foot width of aquifer by the 10-foot thickness of aquifer considered in this evaluation.

This probabilistic evaluation indicates that there is a 95 percent probability that the aquifer dilution factor (representing a minimum DAF for all constituents at the Site) is at least 2,400 (5th percentile value; refer to the dilution factor forecast statistics on page A-4 of Attachment A).

Soil Cleanup Level Determination Results

The results of the Monte Carlo simulation run with the aforementioned input assumptions indicates there is a 95 percent probability that a DNT soil concentration of 3 mg/kg is protective of Site groundwater under a drinking water scenario. The mean value in the DNT soil cleanup level distribution was 59 mg/kg and the most likely value (mode) was 20 mg/kg. Attachment A provides supporting information for the soil cleanup level determination, including forecasts with statistical output (pages A-1 through A-4) and assumptions (pages A-5 and A-6).

Conclusion

There is a high probability that a DNT soil cleanup level of 3 mg/kg will be protective of Site groundwater assuming a hypothetical drinking water exposure. The 3 mg/kg cleanup level was determined from a probabilistic evaluation which incorporated Site-specific data and their inherent uncertainty, while maintaining a high level of conservatism (e.g., not considering any of the dilution or attenuation processes occurring in the thick vadose zone at the Site). Because Site groundwater will not be used for drinking water supply under future use of the Site, higher DNT concentrations than 3 mg/kg in soil would be protective of the highest beneficial use of Site groundwater, which is discharge to surface water.

REFERENCES

Hart Crowser, 1994. Draft Remedial Investigation/Feasibility Study, Former DuPont Works Site, Dupont, Washington. December 22, 1994.

Thorthwaite, C.W., and J.R. Mather, 1957. Instructions and Tables for Computing Potential Evapotranspiration for Water Balance. Publications in Climatology, v. 10, no. 3. Drexel Institute of Technology, Laboratory of Climatology. Centerton, NJ.

Washington State University, 1968. Washington Climate Data for King, Kitsap, Mason, and Pierce Counties. WSU Cooperative Extension Service, College of Agriculture. Prepared in cooperation with US Department of Agriculture. EM 2734.

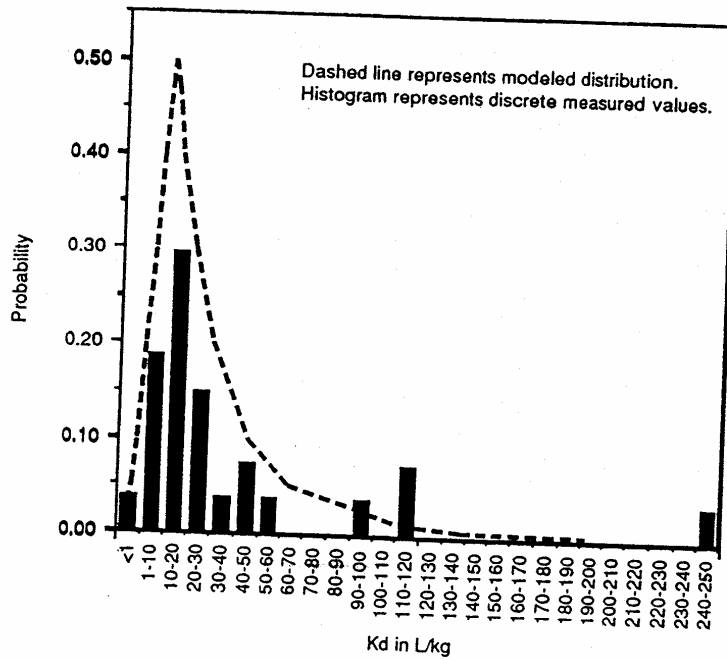
DNTSOIL.rev

Table 1 - TCLP DNT Data and Desorption Coefficient (Kd) Estimates

SMPL-ID	Total DNT (1/2 U) Soil Concentration in mg/kg	Total DNT TCLP Leachate Concentration in mg/L	Desorption Coefficient (Kd) in L/kg
5D-DS-5	330	3.40	97
18-DS-SC-1	113	4.16	27
18-DS-SC-10	96	50	2
5D-DS-4	35	1.74	20
5D-DS-1	30	0.26	117
5D-DS-3	20.6	0.08	248
5-DH-TP-2-S-1	13.2	0.31	43
5D-TP-DS-6-S-3	10.8	44	0.2
18-DS-SC-11	8.7	1.32	7
5D-DS-2	8.6	0.57	15
5D-TP-DS-2-S-3	8.2	0.07	111
18-DS-SC-18	6.7	0.96	7
18-DS-SC-63	6.5	0.19	34
5D-TP-DS-6-S-2	6.2	0.53	12
18-DS-SC-5	6.1	0.13	46
18-DS-48	5.6	0.06	95
18-DS-SC-65	4.1	0.23	18
5D-TP-DS-6-S-4	3.4	0.25	14
5D-TP-DS-2-S-4	2.7	0.16	17
18-DS-SC-79	2.0	0.21	10
5D-TP-DS-3-S-3	1.5	0.06	25
18-DS-SC-68	1.3	0.15	9
18-DS-SC-28	0.3	0.01	24
5-DH-TP-2-S-2	0.07	0.001	52
5-DH-TP-3-S-1	0.04 U	0.002 U	20
5-DH-TP-4-S-1	0.03 U	0.002 U	19
5-DH-TP-1-S-1	0.02	0.002 U	10

No. of Samples:	27
Geometric Mean:	20 L/kg
Geometric Std. Dev:	4.0 L/kg

Comparison of Modeled and Measured Probability Distributions for K_d



Hart Crowser
J-4261-01

ATTACHMENT A
SUPPORTING INFORMATION FOR DNT SOIL CLEANUP LEVEL

Attachment A - Supporting Information for DNT Soil Cleanup Level

Crystal Ball Report

Forecast: DNT Soil Conc for GW Protection in mg/kg

Cell: F32

Summary:

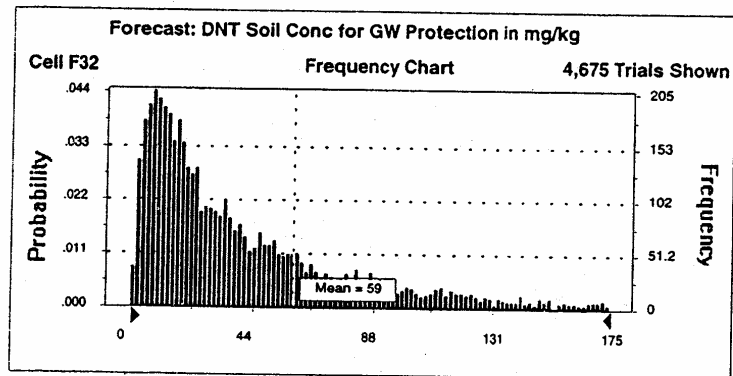
Display Range is from 0 to 175

Entire Range is from 0 to 4011

After 5,000 Trials, the Std. Error of the Mean is 2

Statistics:

	Value
Trials	5000
Mean	59
Median (approx.)	30
Mode (approx.)	20
Standard Deviation	116
Variance	13444
Skewness	15.37
Kurtosis	430.59
Coeff. of Variability	1.97
Range Minimum	0
Range Maximum	4011
Range Width	4010
Mean Std. Error	1.64



Attachment A - Supporting Information for DNT Soil Cleanup Level

Forecast: DNT Soil Conc for GW Protection in mg/kg (cont'd)

Cell: F32

Percentiles:

<u>Percentile</u>	<u>Value (approx.)</u>
0%	0
5%	3
25%	13
50%	30
75%	65
95%	200
100%	4011

End of Forecast

Attachment A - Supporting Information for DNT Soil Cleanup Level

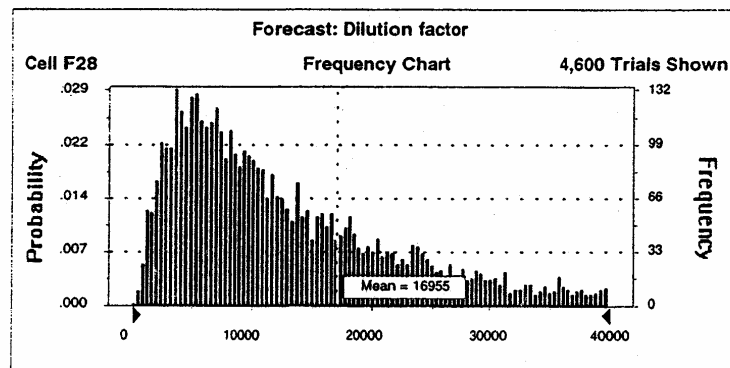
Forecast: Dilution factor

Cell: F28

Summary:

Display Range is from 0 to 40000
Entire Range is from 255 to 382050
After 5,000 Trials, the Std. Error of the Mean is 278

Statistics:	Value
Trials	5000
Mean	16955
Median (approx.)	11140
Mode (approx.)	5981
Standard Deviation	19652
Variance	386216865
Skewness	4.99
Kurtosis	54.30
Coeff. of Variability	1.16
Range Minimum	255
Range Maximum	382050
Range Width	381796
Mean Std. Error	277.93



Attachment A - Supporting Information for DNT Soil Cleanup Level

Forecast: Dilution factor (cont'd)

Cell: F28

Percentiles:

<u>Percentile</u>	<u>Value (approx.)</u>
0%	255
5%	2396
25%	6019
50%	11140
75%	20737
95%	49824
100%	382050

End of Forecast

Attachment A - Supporting Information for DNT Soil Cleanup Level

Assumptions

Assumption: DNT Kd (TCLP) in L/kg

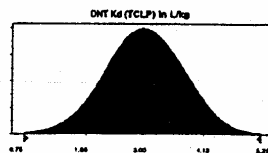
Cell: F29

Lognormal distribution with parameters:

Mean	3.00	(log space)
Standard Dev.	0.75	(log space)

Selected range is from -Infinity to +Infinity

Mean value in simulation was 26.73



Assumption: Precipitation in Inches/year

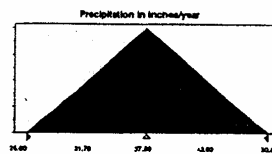
Cell: F18

Triangular distribution with parameters:

Minimum	25.60
Likeliest	37.80
Maximum	50.00

Selected range is from 25.60 to 50.00

Mean value in simulation was 37.72



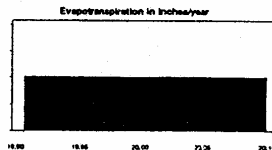
Assumption: Evapotranspiration in Inches/year

Cell: F19

Uniform distribution with parameters:

Minimum	19.90
Maximum	20.10

Mean value in simulation was 20.00



Attachment A - Supporting Information for DNT Soil Cleanup Level

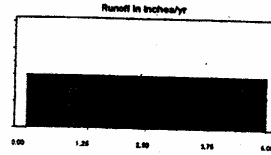
Assumption: Runoff in Inches/yr

Cell: F20

Uniform distribution with parameters:

Minimum	0.00
Maximum	5.00

Mean value in simulation was 2.48



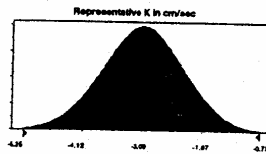
Assumption: Representative K in cm/sec

Cell: B18

Lognormal distribution with parameters:

Mean	-3.00	(log space)
Standard Dev.	0.75	(log space)

Selected range is from -Infinity to +Infinity
Mean value in simulation was 0.07



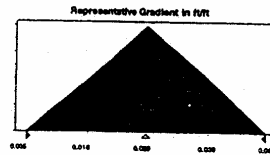
Assumption: Representative Gradient in ft/ft

Cell: B19

Triangular distribution with parameters:

Minimum	0.005
Likeliest	0.028
Maximum	0.050

Selected range is from 0.005 to 0.050
Mean value in simulation was 0.028



End of Assumptions

C.4 Mercury Cleanup Levels Summary and Mercury/Lead Leaching Study

XXXXXXXXXXXXXXXXXXXX
Director



mercury

STATE OF WASHINGTON
DEPARTMENT OF ECOLOGY

7272 Cleanwater Lane, LU-11 • Olympia, Washington 98504-6811 • (206) 753-2353

August 12, 1993

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DuPont Chemicals, B-12230
1007 Market Street
Wilmington, Delaware 19898

Re: Mercury Cleanup Levels Summary and Mercury/Lead Leaching Study

Dear Vern, Linda, and Jack:

This letter transmits the Department of Ecology's (Ecology) comments on the above reports dated July 19, 1993. The Ecology team (Dan Alexanian, Kelly Susewind, and myself) reviewed them and our approval/comments follow.

MERCURY CLEANUP LEVELS SUMMARY:

The Mercury Cleanup Levels Summary report is hereby accepted and approved. The Ecology team agrees with the approaches taken to establish site specific cleanup levels for mercury in soil. Based upon the work conducted by Hart Crowser, the soil cleanup level for mercury is 24.0 mg/kg (equivalent to parts per million (ppm)). That concentration of mercury, which is the Model Toxics Control Act Method "B" soil cleanup level, is protective of human health and the environment, including ground water and surface water. It should be noted that 24 mg/kg is the individual cleanup level for mercury, which may be adjusted downward depending on cumulative site risks associated with multiple hazardous substances or exposure pathways.

We do have comments on a couple statements made in the summary report. The summary report states, "...mercury concentration below 24 mg/kg in site soils will not leach to ground water..." and "...ground water and surface water have not and will not be impacted." These statements are overly definitive in relation to reality. More appropriate would have been statements such as the following, "...mercury concentrations below 24 mg/kg in site soils will not leach to ground water at harmful levels..." and "...ground water and surface water have not and will not be adversely impacted." Over time, be it geologic time, the mercury will eventually leach to ground water or surface water.

P 4, p 4: Flow rate varied between columns due to variations in dry soil density (compactness), and therefore "K".

Page 5, Table 3: Correct the location of the comma in the second column, third row from the top; 8,190 instead of 81,90.

P 6, p 2: The statement that the metals concentration in the leachate was proportional to the initial soil concentration is "a little strong." A preferable statement would be: metals concentration in the leachate increased with increasing initial soil concentrations.

P 6, p 3: "COL-3 ran for approximately twice as long as COL-1 and nearly ~~5~~ 5 times as long as COL-5." In that same paragraph, it refers to other columns with similar soil concentrations. Were other samples with similar concentrations tested? If not, it would be preferable to say " K_d was greater, indicating less leaching" or " K_d was same order of magnitude indicating similar leaching" or some other statement to indicate that the increased contact time did not adversely affect the results.

P 7, Table 5: The table needs to be modified to include another column showing averages. In our connotation, partition coefficient implies some sort of equilibrium, which is better represented by an average. The averages would be: column #1 is 32,000 L/kg, column #2 is 61,000 L/kg, and column #3 is 41,000 L/kg.

P 7, p 1: In that paragraph, please include the TCLP value for lead.

P 8, p 1: What is the "bonding/binding energy values from leaching solution thermodynamics" that is mentioned in that paragraph?

P 8, p 2: "Soil samples were leached using a 1:20 solid to liquid ratio." Is that ratio based upon weight? If by weight, the column tests used an average of 10.98 pounds (4.99 kilograms (kgs)) of soil and 10.28 kgs of water, therefore approximately a 1:2 ratio. Since all column tests reached or approached the detection limit of 0.2 ug/L, it is not too surprising that diluting the leachate ten fold in the ELP tests resulted in mostly non-detects, even with the increased contact. A brief comparison of the solid to liquid ratio for both tests would seem appropriate for the report.

P 10, Table 7: Is sample #ELP-IS-1 a TCLP test sample rather than an extraction leaching procedure sample? It is footnoted in Table 6 that #ELP-IS-1 is a TCLP sample. In general, the Tables need to be "cleaned up" to clearly identify or separate ELP results from TCLP results.

P 10, p 1: The first sentence states that the ELP data ranged from 16,000 to 36,000 L/mg for mercury. It is difficult to call that a "range," especially since those are only two data points and they are duplicate tests. Also, "This is also consistent with observed results from the column testing, indicating that both mercury and lead are preferentially adsorbed to site soils." Please explain how the underlined part of that sentence relates to the rest of that paragraph.

P 10, p 3: It states that a ratio of average leachate concentrations to initial concentrations was used. On page 9, it states soil:water partition coefficients were calculated from leachate and final soil concentrations. Which is it? Also, how did you calculate the lead ELP value of 2.6×10^{-5} ?

P 11, p 1: We calculated that column test contact times ranged from 2 to 6 hours, based on pore volumes. How did you calculate contact times to get a range from 4.5 to 22 hours?

Vern Moore, Linda Rudisell, Jack Frazier
Page 4
August 12, 1993

Because of the importance of these two reports, we want to ensure that they are as accurate and error-free as possible. If you have any questions or would like to arrange a meeting to discuss our comments and your responses on the two reports, please give me a telephone call at (206) 586-0364.

Sincerely,

Mike Blum

Mike Blum
Site Manager
Toxics Cleanup Program

cc: Marian Wineman, Hart Crowser, Inc.
Ralph Palumbo, Heller, Ehrman, White, & McAuliffe
Charles Hunter, DuPont Company Legal Department
Jay Manning, Senior Assistant Attorney General
Ken Johnson, Weyerhaeuser Company
Bob Shedd, Weyerhaeuser Company
Jeff King, DuPont Environmental Remediation Services
William Gorgensen, City of DuPont
Ecology's Weyerhaeuser/DuPont Site Team
Megan White, Toxics Cleanup Program Section Supervisor

Vern Moore, Linda Rudisell, Jack Frazier
Page 2
August 12, 1993

Admittedly, the mercury concentrations would be extremely low and the impact would probably be imperceptible, though the mercury will leach.

Also, in one of the footnotes, it states, "If mercury were leachable to groundwater it would have shown up in the groundwater sampling data since mercury sources have existed at the Site since the early 1900s." Mercury may have been used at the DuPont Works since the early 1900s, but when it was first released (spilled/discharged) into the environment and exposed to leaching and/or gravity is unknown.

MERCURY/LEAD LEACHING STUDY:

The Mercury/Lead Leaching Study report, as explained to me by Marian Wineman, is to be "viewed" as a reference document. Contained within that report is the backup information used or quoted in the Mercury Cleanup Levels Summary as well as information on lead leaching studies conducted at the same time as the mercury work. Currently, the lead leaching study results are not being used for purposes like the mercury data is. The Ecology team kept the above in mind while reviewing the report. Our detailed comments are as follows:

Page (P) 2, paragraph (p) 3: The text says the permeameter can accommodate 8-inch diameter samples up to 18 inches long. The schematic (Figure A-1) says a sample length of up to 12 inches. Which is it?

P 3, p 2: A hydraulic conductivity (K) of 3×10^{-5} cm/sec puts the recompacted sample in the silt range or the bottom of the silty sand range. In the Mercury Cleanup Levels Summary report (page V-2), it states that a K of 10^{-3} is at the lower end of the range of K estimates. It seems that the test material has an artificially low permeability. What potential effect (under estimated leachability? over estimated leachability?) does this decreased hydraulic conductivity have on the results? Does the over-compacted (lower permeability) sample increase contact times? Does it create preferential flow paths thereby decreasing contact time? A different effect? A couple other related issues (possible discrepancies or errors) were noted in the document.

In that paragraph and Attachment B, it refers to COL-IS-5. Figure B-2 identifies the sample as COL-IS-5. On Table C-1, it refers to sample COL-IS-3 (with the same hydraulic conductivity as COL-IS-5). Are the samples identified correctly or are they all really COL-IS-5?

On Table C-1, shouldn't the ratio between before and after results be the same for "water content" and "saturation"?

Is the hydraulic conductivity of sample COL-IS-5 actually 3×10^{-5} . That seems low for a sample containing 85% gravel and sands and only 16% silts and clays? It would be helpful to see the raw data sheets for computing hydraulic conductivity. Were hydraulic conductivities calculated for the other samples?

P 4, p 3: It states that the actual conditions for each column are summarized in Table 2. Table 2 only has a permeability number for Column #3 and none for columns 1 and 5. Are those permeabilities available?

P 4, Table 2: Columns 1 and 5 have the same dimensions but differ in weight by greater than 8%, therefore the density should also differ by 8%. Shouldn't the density for column 5 be 98 lb/ft³ instead of 105? $[18.48 / 19.99 (106) = 98 \text{ lb/ft}^3]$

Also, on Table 2: The dry density for column 3 should be 117 rather than 116 lb/ft³.

C.5 TNT Soil Cleanup Level Protective of Groundwater



STATE OF WASHINGTON
DEPARTMENT OF ECOLOGY

P.O. Box 47775 • Olympia, Washington 98504-7775 • (360) 407-6300

January 11, 2001

Mr. Jim Odendahl
Weyerhaeuser Company
Post Office Box 100
DuPont, WA 98327-0100

Mr. Ron Buchanan
DuPont Specialty Chemicals
Barley Mill Plaza Building 27
Post Office Box 80027
Wilmington, DE 19880-0027

Re: Hot Spot Interim Action Report

Dear Jim and Ron:

The Ecology Team has reviewed the report entitled Hot Spot Interim Action Report dated October 4, 2000 and we have the following comments. I apologize for my delay in getting your our comments, as Dan Alexanian provided me with his comments a while ago.

1. Page 1, Section 1.1, Third paragraph: The Method C industrial soil cleanup level for trinitrotoluene (TNT) is identified in the report as 33 mg/kg. That level is the Method B concentration based on direct contact as a carcinogen. The Method C industrial cleanup levels are as follows:
Direct contact as a carcinogen - 4,380 mg/kg
Direct contact as a non-carcinogen - 1,750 mg/kg
Protective of groundwater as a carcinogen (100x the groundwater standard) - 2.92 mg/kg
Protective of groundwater as a non-carcinogen (100x the groundwater value)- 1.75 mg/kg
Based on protection of groundwater, the cleanup level would be 1.75 mg/kg, not 33 mg/kg. If you have some site-specific data on TNT and the leachability, that cleanup level might increase or decrease. It does look however, based on the existing sampling data, that TNT is not an issue anymore in the industrial area located north of Sequelitchew Creek. Prior sampling revealed higher TNT concentrations in Area 10 north of the creek.

January 11, 2001
Page 2

2. Page 2, 2nd paragraph (and other locations in the report): "Sample 26-B-503-S-1 is located in a future Placement Area and was not removed because it will be covered with more than 15 feet of fill." The Ecology Team has some philosophical concerns about burying high levels of hazardous substances (25,000 mg/kg lead, for example), even when it is buried 15 feet or more and does not pose a threat to ground water. We should discuss this more in the near future. While it does comply with the Model Toxics Control Act regulations, it seems that if the material is easily accessible, it should be dealt with rather than just covering it over. If you continue with your proposal, you need to ensure that a minimum of 15 feet of fill is placed over those locations with "higher" contaminant concentration.

3. Page 17, Section A3: "In selected cases where the impacted soils are greater than 1.5 feet deep, the initial excavation was 10 feet by 10 feet." Why was 10 by 10 chosen rather than 50 by 50?

4. Pages 21 and 22, Section B7, the bullets: Please explain the statement "...therefore, no data were qualified." It appears from the various statements that there were problems in the lab with lead matrix spike recovery or control limits, but "no data were qualified". Only 2 of 17 bullets identified data that were qualified, though it appears that all the matrix spikes/blank spikes had problems.

5. General comment: It is hard to figure out how to compare original samples with post-excavation confirmational samples.

If you have any questions regarding the above comments, please give me a telephone call at (360) 407-6262.

Sincerely,

Mike Blum

Mike Blum
Site Manager
Toxics Cleanup Program

MB:dj

cc: Izzy Zanikos, DuPont Company
Marian Wineman, URS
Jeff King, West Shores Corporation
Brad Grimsted, Pioneer Technologies Corporation
Ecology's Weyerhaeuser/DuPont Site Team

C.6 TPH Soil Cleanup Level Protective of Groundwater

C.6.1 Review of TPH Soil Cleanup Level Protective of Groundwater

**REVIEW OF TPH SOIL CLEANUP LEVEL
PROTECTIVE OF GROUNDWATER
FORMER DUPONT WORKS SITE
DUPONT, WASHINGTON
FEBRUARY 12, 1996**

In recent discussions regarding residual Bunker C-derived TPH concentrations and backfilling of the Area 8 pipeline excavation (January 18, 1996, meeting), Ecology stated that they perceived inconsistencies in the TPH/PAH Cleanup Level Summary regarding a TPH concentration protective of Site groundwater (7,600 mg/kg vs. 11,000 mg/kg).

Response

There is evidence to support a Bunker C-derived TPH soil concentration of 30,000 mg/kg as protective of Site groundwater. The evidence is summarized below.

- ▶ Because the risk posed by Bunker C-derived TPH at the Site is associated with its cPAH content, a groundwater protection soil cleanup level for Bunker C-derived TPH was derived based on cPAH content in the TPH/PAH Cleanup Level Summary. In Appendix VI of that document, a Bunker C-derived TPH concentration of 7,600 mg/kg was determined by calculating a cPAH concentration protective of groundwater and back-calculating the corresponding TPH concentration from the TPH/cPAH regression (with 95% confidence; Appendix V of the TPH/PAH Cleanup Level Summary). A cPAH concentration of 12 mg/kg was initially calculated as protective of groundwater using the most stringent MTCA cPAH drinking water screening level (0.000012 mg/L), a conservative literature-derived value for cPAH partition coefficient (9,600 L/kg), and a conservative default dilution/attenuation factor (DAF) of 100.

Applying the Site-specific DAF of 2,100 (refer to DNT Soil Cleanup Level Determination; October 1995) rather than a default DAF of 100 indicates that a cPAH concentration of 240 mg/kg is protective of Site groundwater. This corresponds to a Bunker C-derived TPH concentration above 30,000 mg/kg (as protective of Site groundwater). This value is consistent with preliminary findings from the Total Petroleum Hydrocarbon Criteria Working Group (TPHCWG). In the January 17, 1996, meeting of Ecology's Risk Assessment Forum TPH subcommittee, the TPHCWG presented example risk-based

groundwater protection cleanup goals of 35,000 mg/kg for motor oil, and higher (soil saturation [e.g., 25 percent TPH]) for weathered motor oil which is more representative of Bunker C-derived TPH at the Site.

- ▶ Leachable TPH was not detected in TCLP testing of Site soil samples with Bunker C-derived TPH concentrations up to 11,000 mg/kg. Leachable TPH was detected (16 mg/L) in a sample of Site soil with 19,000 mg/kg TPH, as reported in Appendix VI of the TPH/PAH Cleanup Level Summary and the Area 8 Interim Status Memorandum. Applying the Site-specific DAF of 2,100 to this leachate concentration produces a resultant estimated groundwater concentration of only 0.008 mg/L, well below the MTCA groundwater screening level of 1 mg/L. Alternatively, a Bunker C-derived TPH groundwater protection soil cleanup level which represents a soil saturated with Bunker C-derived TPH is determined from these data by multiplying a TPH desorption coefficient (K_d) of 1,200 L/kg ($19,000 \text{ mg/kg} \div 16 \text{ mg/L}$) by the DAF of 2,100 (MTCA groundwater screening level is 1 mg/L). As stated above, the TPHCWG's preliminary findings likewise indicate that soils fully saturated with high molecular weight hydrocarbons (like Bunker C) pose no risk to groundwater.
- ▶ After decades of rainwater leaching of residual TPH in Site soils, detection of TPH and cPAHs has not been confirmed in Site groundwater.

Conclusion

Site-specific data, corroborated by the findings of the TPHCWG, indicate that Bunker C-derived TPH concentrations of 30,000 mg/kg in Site soils will not adversely impact Site groundwater. This value is higher than the previous determination because it includes a more realistic assessment of the substantial natural dilution/attenuation occurring at the Site (Site-specific DAF of 2,100 compared to a default of 100).

SG/rkb
tph.rpt

ECOLOGY MEETING

February 15, 1996

Attendees: Mike Blum, Dan Alexanian, Kelly Susewind, Vern Moore, Jeff King, Steve Germit, Marian Wineman, Geneva Smith

Paraffin Investigation

The Weyerhaeuser/DuPont team reported they had conducted additional sampling in Areas 6, 12, and 38 in order to verify the presence of paraffin wax-derived TPH. A Paraffin Investigation report was presented to Ecology which outlined details of the soil sampling, analysis results, and exploration location maps.

Area 6, Crystallizer Drum Area

Oil was detected in the two surface soil samples that were taken. The results did not confirm paraffin as the source of TPH.

Area 12, Works Magazine Landfill

Fourteen confirmation soil samples were collected from RI and pre-RI sampling locations where elevated TPH and/or oil and grease were detected. It was determined that paraffin associated with waxed cardboard boxes most likely accounted for the majority of TPH detected during the RI sampling. Low concentrations of diesel were detected in three of the samples.

Mike Blum of Ecology stated that the samples taken from Unit 12-2 did not necessarily confirm that all the TPH was paraffin-based. Additional sampling might provide extra support.

Marian Wineman of the Weyerhaeuser/DuPont team stated there were many variabilities in Area 12 and paraffin was very patchy throughout the area, which could result in patch hits. Three monitoring wells in the location have not detected TPH. She also stated that the chromatogram for paraffin was nearly identical to the chromatograms from Area 12.

Area 38, Carton Production Area and Drywell

TPH concentrations above the MTCA screening level were detected in three RI samples in Area 38. Interim source removal was conducted in October 1995 and verification samples were taken. Paraffin was not detected in any of the samples. Oil and diesel were detected.

Path Forward:

Ecology will review Paraffin Report and decide whether or not additional sampling will be needed.

Review of TPH Soil Cleanup Level Protective of Groundwater

Discussion on residual Bunker C-derived TPH concentrations and the backfilling of Area 8 pipeline excavation. The Weyerhaeuser/DuPont team responded to Ecology questions regarding inconsistencies in the TPH/PAH Cleanup Level Summary regarding a TPH concentration protective of Site groundwater. Steve Gerriat of the Weyerhaeuser/DuPont team stated that site-specific data indicated that Bunker C-derived TPH concentrations of 30,000 mg/kg in Site soils would not adversely impact the groundwater.

Mike Blum of Ecology stated that Ecology did not necessarily agree with the 30,000 mg/kg number. He stated that in general, the TPH values were probably protective of groundwater using the DAF. There is concern about the PAH's since chrysene is showing up in some of the monitoring wells.

Dan Alexanian of Ecology stated that the proposed monitoring well would be down-gradient from Area 8 and could be used to monitor PAHs, as well as DNT. Mike Blum gave approval for Area 8 to be backfilled, but stated the PAH in groundwater still needed to be dealt with in determining TPH soil cleanup levels protective of groundwater. Dan Alexanian agreed with this on the condition that if necessary (after the PAC decision), the Weyerhaeuser/DuPont team would come back in and clean up locations which exceed the PAC's number.

Path Forward:

- *Area 8 to be backfilled.*
- *Ecology to review TPH/cPAH data with regards to establishing Site TPH soil cleanup levels.*
- *Weyerhaeuser/DuPont team to tabulate all sample concentrations exceeding MTCA screening levels at depths below 15 feet.*

Other Issues

Discussion on arsenic background number of 32 ppm. Ecology agrees with the work that has been done and with the 32 ppm number.

Path Forward:

- *Parcel 2 draft RI package to Ecology. (22 March 1996)*
- *W/D will initiate first draft of Parcel 2 CAP.*

Schedule for remainder of the Site was discussed. It could take more than two years for the PAC to come up with recommendations, for Ecology to put together some policies, and get changes made in the regulations. Mike Blum stated Ecology would like to begin making some decisions for this site.

Vern Moore stated that the golf course alternate plan would be submitted to the City of DuPont around the middle of March. It is grandfathered under the City's 1985 Comprehensive Plan. The Weyerhaeuser/DuPont team would like to see the Department of Ecology sponsor the EIS, lending more efficiency and speed to the

project. The Weyerhaeuser/DuPont team gave Ecology a 2001 to 2002 estimate for completion of the cleanup.

Ecology will confirm with the Weyerhaeuser/DuPont team a date for a general meeting with everyone invited. (This has been confirmed for 3/19/96 8:30 am - 12 noon at DuPont field office).

C.6.2 TPH/PAH Cleanup Level Summary

file: Final
Draft

DRAFT

TPH/PAH CLEANUP LEVEL
SUMMARY

INTRODUCTION

The appropriate soil cleanup levels for total carcinogenic polycyclic aromatic hydrocarbons (cPAH) in each land use area at the Former DuPont Works Site (the "Site") are as follows:¹

<u>Land Use</u>	<u>cPAH</u>
Residential	1 to 10 mg/kg
Open Space	5 to 50 mg/kg
Golf Course	20 to 220 mg/kg
Industrial	30 to 300 mg/kg

The appropriate soil cleanup levels for Bunker C fuel-derived total petroleum hydrocarbons (TPH) are 3,100 to 27,000 mg/kg.

TPH/cPAH cleanup levels for groundwater are not established because groundwater and surface water at the Site are in compliance with MTCA screening levels.

¹ Soil cleanup levels apply to soils from 0 to 15 feet in depth. WAC 173-340-740(6)(c).

TPH AND cPAH DETECTED AT THE SITE

TPH and/or cPAH concentrations above MTCA screening levels were detected at 15 areas of the Site. Interim source removal actions have been conducted in eight of those areas. TPH and/or cPAH concentrations above MTCA screening levels remain only in two of these interim source removal areas: Area 5 (mixed petroleum products) and Area 8 (Bunker C fuel-derived TPH). An interim source removal action in Area 24 will be conducted in 1994, and verification data will determine whether TPH/cPAH concentrations above MTCA screening levels remain.

Six additional (non-source removal) areas contain TPH and/or cPAH concentrations above MTCA screening levels. Areas 7 and 16 contain Bunker C fuel-derived TPH. Area 26 contains mixed petroleum products. Areas 6, 12 and 38 contain non-hazardous paraffin-derived TPH. No toxic fraction is associated with paraffin-derived TPH, and no cPAHs were detected in any of these three areas. Accordingly, no further action based on petroleum constituent concentrations is proposed for the three areas with nonhazardous paraffin-derived petroleum constituents.

Appendix I summarizes TPH and cPAH concentrations in soil in each area of the Site that has had concentrations above MTCA screening levels, and provides information regarding the source of petroleum constituents for each area. Appendix II describes

the TPH/cPAH composition of the Bunker C fuels present at the Site.

CLEANUP LEVELS FOR TPH/cPAH IN SOILS

1. Soil cleanup levels for cPAH. The MTCA Cleanup Regulation requires establishment of cleanup levels based on estimates of the reasonable exposures expected to occur under both current and future site use conditions. WAC 173-340-740(1)(a).

The City of Dupont 1985 Comprehensive Land Use Plan for the area South of Sequalitchew Creek will result in that area being used exclusively for residential, recreational and commercial uses. Recreational uses may include an 18-hole golf course (that will cover a significant portion of the area South of Sequalitchew Creek) and open space, or "green belts," along the Creek, in the kettle areas, and around Old Fort Lake. Commercial uses will cover the remaining areas that are not specifically developed as residential neighborhoods. The cPAH cleanup levels were developed for each planned residential and recreational land use area.² Cleanup levels were also developed for the industrial areas of the Site that are located North of Sequalitchew Creek.

² Residential cleanup levels will apply in the commercial areas because many commercial areas will have mixed commercial and residential uses.

The cPAH cleanup levels for residential land use are derived using exposure assumptions that are representative of chronic exposures with children as the sensitive receptor population. (Note, however, that cPAH has not been detected above MTCA screening levels in areas currently planned for residential development.)

The cPAH cleanup levels for open space land use are derived using reasonable exposure assumptions representative of children in a recreational setting. Soils in the areas of the Site planned for open space uses will not be disturbed by activities typical in residential areas such as gardening and landscaping. Landscaping and vegetative ground cover will further reduce the availability of surface soils for direct contact. However, incidental soil ingestion by children has been considered in setting the cleanup levels for cPAH in open space areas.

The cPAH cleanup levels for golf course land use are derived using exposure assumptions appropriate to golf course maintenance workers. Golfers (and other persons with access to the golf course) would not be potentially exposed to residual constituents in native soils because the entire golf course area will be covered by 1 to 2 feet of topsoil and golf course turf grasses.³

³ Some golf course areas may also be covered by concrete or asphalt roads, parking lots, golf cart paths, and by structures such as a club house, maintenance and storage buildings, etc.

Thus, the only potentially exposed persons would be golf course workers (adults) who occasionally may come into contact with native soils during maintenance of the golf course. Exposure in these circumstances would be infrequent and of limited duration.

The cPAH cleanup levels for industrial land use are derived using exposure assumptions appropriate to protect an adult worker that might have daily contact with Site soils.

In accordance with WAC 173-340-708(3)(c), documentation for the use of Site-specific exposure scenarios is provided in Appendix III.

2. Soil cleanup levels for TPH. The risk presented by the Bunker C fuel constituents detected at the Site is attributable to its cPAH components. See Appendix IV. Accordingly, correlation analyses were performed to assess the statistical relationship between cPAH and TPH concentrations, and to establish TPH cleanup levels for Bunker C fuel-derived TPH detected in Areas 7, 8 and 16.⁴ See WAC 173-340-702(6) (Ecology "shall consider new scientific information when establishing cleanup levels for individual sites").

⁴ No TPH cleanup level is established for Areas 5 and 26 that have mixed petroleum products because cleanup of metals contamination in those areas will also cleanup soils with petroleum constituents. Verification testing will be done in those areas to confirm that no TPH concentrations remain above MTCA screening levels.

The results indicate that cleanup levels of 3,100 to 27,000 mg/kg for Bunker C fuel-derived TPH will correspond to the residential cleanup goal of 1 to 10 mg/kg for cPAH. Appendix V explains the analysis used to establish TPH cleanup levels. See also, WAC 173-340-740(3)(ii)(B).

TPH/CPAH CONCENTRATIONS IN SITE GROUNDWATER AND SURFACE WATER DO NOT POSE A RISK TO HUMAN HEALTH

TPH/cPAH cleanup levels are not established for groundwater because TPH/cPAH concentrations are not present above MTCA screening levels in groundwater or surface water at the Site. Appendix VI sets forth TPH/cPAH concentrations detected in Site groundwater and surface water during RI sampling.

- TPH was not detected in any groundwater or surface water sample collected during the four rounds of RI water sampling;
- no groundwater samples had detections of any noncarcinogenic PAH above the MTCA drinking water screening levels;
- no groundwater sample had detections of total cPAH above the MTCA screening level, except a single unconfirmed detection in one well that is not considered representative of groundwater quality;

- no TPH or noncarcinogenic PAHs were detected above MTCA screening levels in any surface water samples; and
- no cPAH were detected in any surface water sample, except a single detection which was the result of elevated sample turbidity and which is not representative of surface water quality at the Site.

TPH/PAH CONCENTRATIONS IN SITE SOILS, GROUNDWATER AND SURFACE WATER ARE PROTECTIVE OF ECOLOGICAL RECEPTORS

A quantitative ecological risk assessment was performed to estimate the potential risk posed by TPH/cPAH in soils at the Site. See Appendix VII.

The results of the ecological risk assessment indicate that cPAH concentrations in soil below 30 mg/kg are protective of ecological receptors at the Site. No cPAH-related ecological risks would be present in the residential areas of the Site at the TPH cleanup levels ranging from 1 to 10 mg/kg. cPAH concentrations in the open space areas of the Site are less than 30 mg/kg. Finally, there will be no risk to ecological receptors in the golf course area because the topsoil cover, golf course turf grasses and golf course maintenance will minimize small mammal exposure to the underlying subsurface soils.

The risk to ecological receptors from exposure to Bunker C fuel-related TPH is attributable to its cPAH components. The cPAH concentration of 30 mg/kg determined to be protective of ecological resources corresponds to a TPH soil concentration of 76,000 mg/kg. Thus, at the cleanup levels established for TPH (3,100 to 27,000 mg/kg), Site soils will not present a risk to ecological receptors.

CONCLUSION

The following soil cleanup levels for cPAH/TPH are established based on land use:

1. For residential land use, the appropriate cPAH cleanup level is 1 to 10 mg/kg;
2. For open space land use, the appropriate cPAH cleanup level is 5 to 50 mg/kg;
3. For golf course land use, the appropriate cPAH cleanup level is 20 to 220 mg/kg;
4. For industrial land use, the appropriate cPAH cleanup level is 30 to 300 mg/kg.

5. For soils that contain Bunker C fuel-derived TPH, the appropriate cleanup level is 3,100 to 27,000 mg/kg.

The cPAH/PAH cleanup levels set forth above are protective of ecological receptors. No groundwater risk is present at the Site because TPH/cPAH concentrations in groundwater are well below MTCA screening levels.

H:\RHP\WEYERH\EXPC3.TPH

LIST OF TECHNICAL APPENDICES
TPH/PAH CLEANUP LEVEL SUMMARY

- I. Summary of TPH/PAH in Soils
- II. Bunker C TPH/PAH Composition
- III. Development of cPAH Soil Cleanup Levels for Designated Land Uses at the Site
- IV. Human Health Toxicity of TPH/PAHs
- V. Bunker C TPH Cleanup Level
- VI. Groundwater, Surface Water, and Leachability Data for TPH and cPAHs
- VII. Potential Ecological Risk of TPH/cPAH

APPENDIX I SUMMARY OF TPH/PAH IN SOILS

Total petroleum hydrocarbons (TPH) have been detected in soil samples collected from 15 areas of the Site. Based on historical records and chemical fingerprinting (chromatogram) analyses, the primary source of the TPH on the Site is Bunker C fuel. However, a few Site areas have TPH detections associated with sources other than Bunker C fuel, including mixed petroleum types (gasoline, kerosene, and diesel formerly occurred in former UST locations) and paraffin.

Because MTCA allows for the evaluation of the toxic fraction of TPH (WAC 173-340-730[3][ii][B]), TPH-containing soils were also analyzed for polycyclic aromatic hydrocarbons (PAHs) and/or benzene, toluene, ethylbenzene, or xylenes (BTEX) depending on the petroleum type.

Of the 15 areas where TPH has been detected, interim source removal has been conducted in eight areas, and interim source removal is planned for a ninth area (Area 24, Main Powerhouse) in 1994. Ecology has reviewed verification sampling data for three of these areas and has determined that No Further Action (NFA) is needed in these areas.

Interim Source Removal Areas Approved by Ecology for No Further Action

- ▶ **Area 20—Underground Storage Tanks.** Four underground storage tanks which formerly contained kerosene, diesel, or gasoline, have been removed and the associated petroleum-containing soils overexcavated (Hart Crowser, 1991);
- ▶ **Area 38—Box Production Area Underground Storage Tank.** Diesel and/or Bunker C were identified in one underground storage tank, which has been removed, and the associated petroleum-containing soils overexcavated (Hart Crowser, 1993); and
- ▶ **Area 39—Laboratory Underground Storage Tank.** Gasoline was identified in one underground storage tank, which has been removed, and the associated petroleum-containing soils overexcavated (Hart Crowser, 1993).

These three areas, which have been approved by Ecology for NFA, will not be addressed further. Area 24, the Main Powerhouse, is scheduled for interim source removal during 1994.

The remaining eleven areas are addressed below according to the petroleum type identified in each area.

Bunker C-Derived TPH

Analysis of Bunker C-Derived TPH

Fourteen soil and product samples from the Area 8 pipeline were analyzed for fuel identification (EPA Method 8015 Modified) or volatile organic compounds (EPA Method 8240). Bunker C was identified in eight of these samples. No BTEX was detected in any of the samples where Bunker C was identified.

Based on these results, it was determined that BTEX was not representative of the toxic fraction of Bunker C-derived TPH (WAC 173-340-740[3][ii][B]).

Carcinogenic PAHs (cPAHs) were detected in each area with elevated concentrations of Bunker C-derived TPH. Non-carcinogenic PAHs were not detected at the Site above MTCA screening levels, and therefore will not be addressed further.

Areas where Bunker C occurs include Areas 7, 8, 16, and 24. The appropriate cleanup level for TPH in these areas was determined on the basis of a correlation evaluation of the TPH and corresponding total cPAH concentration (toxic fraction per WAC 173-340-740[3][ii][B]) and future land use, as described in Appendix V.

Additional discussion of Bunker C-derived TPH in Areas 7, 8, and 16 is provided below. Area 24 is not discussed because interim source removal is planned for later in 1994.

Interim Source Removal of Bunker C-Derived TPH in Area 8

The objective of the Area 8 interim source removal was to excavate soils containing total cPAH concentrations above 1 mg/kg to a depth of 15 feet (WAC 173-340-740[6][c]).

Post-removal TPH concentrations in the upper 15 feet of soil ranged from not detected (ND) to 200 mg/kg. Post-removal cPAH concentrations in samples in the upper 15 feet of soil were all below detection limits. Post-removal TPH concentrations of soil at depths greater than 15 feet ranged from not detected to 11,000 mg/kg. Post-removal total cPAH concentrations of soil at depths greater than 15 feet ranged from not detected to 4.4 mg/kg. Based on the total cPAH/TPH correlation and

considerations of TPH leachability, all targets associated with cPAH and groundwater protection have been achieved by the interim source removal. The cPAH/TPH correlation evaluation is discussed in Appendix V. TPH leachability is discussed in Appendix VI. Table I-1 summarizes TPH/cPAH concentrations in Area 8.

Table I-1 - TPH and cPAH Concentrations in Area 8 Following Interim Source Removal

Area	Range of Concentrations in mg/kg	Detection Frequency	Arithmetic Mean in mg/kg	95 Percent UCL in mg/kg
TPH				
8 (< 15 ft)	ND to 200	6/17	40	200
8 (all depths)	ND to 11,000	32/48	1,300	11,000
Total cPAH				
8 (< 15 ft)	ND	0/6	ND	ND
8 (all depths)	ND to 4.4	2/13	0.4	4.4

ND: Not detected. TPH detection limit of 21 mg/kg; cPAH detection limit of 0.06 mg/kg.

Bunker C-Derived TPH in Areas 7 and 16 (Non-Interim Source Removal Areas)

A surficial layer of Bunker C residue is present in portions of the bottoms of the Area 7 and Area 16 kettles (Hart Crowser, 1992a). Fuel identification analyses performed on samples of the residue from each of these areas confirm that weathered and unweathered Bunker C residue is present in each area, and the residues in each area are similar (refer to Appendix II). Table I-2 presents TPH and cPAH data for Areas 7 and 16.

Table I-2 - TPH and cPAH Concentrations in Areas 7 and 16 (Bunker C-Derived TPH)

Area ⁽¹⁾	Range of Concentrations in mg/kg	Detection Frequency	Arithmetic Mean in mg/kg	95 Percent UCL in mg/kg
TPH				
7	ND to 10,000	15/29	960	10,000
16	ND to 2,500	29/51	310	2,200
Total cPAH				
7	ND to 2.9	5/7	0.8	2.9
16	ND to 17.9	8/19	1.5	17.9

ND: Not detected. TPH detection limit of 21 mg/kg; cPAH detection limit of 0.06 mg/kg.

⁽¹⁾ Concentrations are summarized for samples above 15 feet because, where sampled, no detections of TPH or cPAH occurred below 15 feet in these areas with the exception of one sample with 28 ppm TPH in Area 16.

Mixed Petroleum-Derived TPH

Analysis of Mixed Petroleum-Derived TPH

BTEX was detected in soils formerly associated with USTs, which have been removed during interim source removal in Areas 20, 38, and 39. Ecology has determined that NFA is required in these areas (see above).

Areas found to contain mixed petroleum products are Areas 5, 19, 35, 26, 40, and one subunit of Area 12, Area 12-2. These areas are discussed below, with the exception of subunit Area 12-2 which is discussed in the ***Non-Hazardous Paraffin-Derived TPH*** section below.

Interim Source Removal Areas - Mixed Petroleum-Derived TPH

Area 5. Area 5 formerly contained debris deposited and partially buried on the western slope of the Area 16 kettle. The area has been used since at least the 1940s for disposal of non-burnable materials. Prior to debris removal activities in the area, the debris included a variety of containers including drums, demolition debris, and general refuse. The majority of the drums removed were apparently empty and non-hazardous. However,

85 drums contained mixed petroleum products (oil, tar, grease, and asphalt), which contributed to elevated TPH concentrations in this area.

Area 5 interim source removal was based on excavating soils with elevated concentrations of DNT, metals, TPH, and PAHs. Following the interim source removal, verification soil samples collected from the area contained TPH concentrations ranging from not detected to 1,900 mg/kg. Verification data for cPAHs indicated concentrations ranging from 0.3 to 2.4 mg/kg.

The mixed petroleum products detected in Area 5 are associated with concentrations of other constituents above MTCA screening levels, mainly lead and arsenic. Cleanup of soils for lead and arsenic will remove all TPH-containing soils above the MTCA screening level, therefore, it is unnecessary to establish cleanup levels for TPH in this area.

Area 19. Petroleum-containing soil from the area around the Oil House was excavated and removed. Verification soil sample results indicated concentrations in samples ranging from below detection limits to 29 mg/kg, well below the MTCA screening level. Therefore, TPH will not be addressed further in this area.

Area 35. Three drums containing a solidified tar-like substance were removed. Verification soil sample results indicated TPH concentrations were below detection limits. Therefore, TPH will not be addressed further in this area.

Area 40. Soils from a drywell at the Press House in Area 40, which previously contained TPH and PAH concentrations above screening levels, were excavated during interim source removal. Verification soil sample results indicated that concentrations of TPH were below detection limits. Therefore, TPH will not be addressed further in this area.

Table I-3 provides TPH and cPAH data for interim source removal Areas 5, 19, 35, and 40.

Table I-3 - TPH and cPAH Concentrations in Mixed Petroleum-Derived TPH Areas Following Interim Source Removal

Area ⁽¹⁾	Range of Concentrations in mg/kg	Detection Frequency	Arithmetic Mean in mg/kg	95 Percent UCL in mg/kg
TPH				
5	ND to 1,900	45/85	130	330
19	ND to 70	2/13	19	70
35	ND	0/3	ND	ND
40	ND	0/2	ND	ND
Total cPAH				
5	0.33 to 2.4	8/8	1.3	2.4
19	0.28	1/1	—	—

ND: Not detected. TPH detection limits of 20 to 50 mg/kg; cPAH detection limit of 0.06 mg/kg.

⁽¹⁾ Concentrations are summarized for samples above 15 feet because, where sampled, no detections of TPH or cPAH occurred below 15 feet in these areas.

Mixed Petroleum-Derived TPH in Area 26 (Non-Interim Source Removal Area)

Area 26 (Unit 26A) Kettle. Area 26 includes the facilities used for reconstruction of spent acids returning from the nitroglycerin production area. One of the two kettles (Unit 26A) located south of the recovery facilities reportedly received liquid discharge from several sources, including the vehicle maintenance and truck wash facility. TPH concentrations above the MTCA direct contact screening level were detected in surface soil samples collected from several locations on the northern portion of the kettle floor, and are a mixture of petroleum products derived from the vehicle maintenance facility (Table I-4). Fuel fingerprint analysis (EPA Method 8015 Modified) identified the substance as heavy oil. The results are distinctly different from Area 7 and Area 16 (kettles) fuel identification results, which indicated Bunker C. No Bunker C residue is evident in the Unit 26A kettle.

Soil samples, which contained TPH above MTCA screening levels, also contained concentrations of other constituents, mainly lead. Cleanup of

soils for lead will remove TPH-containing soils above the MTCA screening level, therefore, it is unnecessary to establish cleanup levels for TPH in this area.

Table I-4 - TPH and cPAH Concentrations in Area 26 (Mixed Petroleum-Derived TPH)

Area ⁽¹⁾	Range of concentrations in mg/kg	Detection Frequency	Arithmetic Mean in mg/kg	95 Percent UCL in mg/kg
TPH				
26	ND to 5,600	15/47	380	810
Total cPAH				
26	ND to 37.0	9/11	4.1	37.0

ND: Not detected. TPH detection limit of 21 mg/kg; cPAH detection limit of 0.06 mg/kg.

⁽¹⁾ Concentrations are summarized for samples above 15 feet because, where sampled, no detections of TPH or cPAH occurred below 15 feet in these areas.

Non-Hazardous Paraffin-Derived TPH

Analysis of Paraffin-Derived TPH

Paraffin wax is a white, semi-translucent, flammable, odorless solid (Clayton and Clayton, 1982). It is a mixture of solid, high molecular weight (C-30 to C-40 range) hydrocarbons, primarily alkanes derived from petroleum sources (Sax, 1987). Paraffin is insoluble in water and is soluble in organic solvents and oils (Sax, 1987). Paraffin wax is used for coating paper and food containers, medicinal agents, candles, sealant, and chewing gum base. Paraffin wax is biologically inert for the Site exposure routes (RTECS, 1994).

The TPH analysis (EPA Method 418.1) does not distinguish between paraffins and other petroleum-derived products; however, historical Site use and field observations conducted during the RI confirm that only waxes and paraffins are present in Areas 6, 12, and 38. Historical information indicates that paraffin was used as a protective coating on boxes and cartons used to pack and ship Site products. Paraffin-containing drums or paraffin-coated boxes were found in each of these three areas. In addition, no cPAHs were detected in any of these three areas. Since cPAHs were

not detected in soil samples collected from the three areas (Areas 6, 12, and 38) and there is no toxic fraction associated with the paraffin-derived TPH, the TPH will not be addressed further in these areas.

Area 6. Area 6 was used for disposal of defective 55-gallon ammonium nitrate drums used at the ammonium nitrate plant. A total of 1,600 drums were removed from this area during interim source removal. Except for seven drums, the drums were empty. The non-empty drums contained residual ammonia salts and paraffin, as identified by field screening analysis. Soil samples above the MTCA screening level were confined to surface samples (0 to 1 foot in depth). The soil TPH detections in this area are associated with residue from the paraffin-containing drums. No other potential TPH sources were identified in the historical records or field observations for this area.

Area 12. Wastes related to explosives packaging activities in the Works Magazine were buried in shallow excavations in several areas of the Works Magazine landfill. Waste materials buried include explosives packaging, auto shop wastes, empty ammonium nitrate drums, and residual monomethylamine nitrate (MMAN). Five of seven Area 12 landfill units contain elevated TPH concentrations. The highest concentrations of TPH were detected in samples from locations containing paraffin-coated cardboard, residual MMAN, and mixed solid waste. Mixed solid waste found in Area 12 consisted of various materials, including metal strapping, miscellaneous plastic bags, foam rubber, wood debris, cloth, and rubber hose. The TPH detections are associated with the paraffin coating on the cardboard packaging.

cPAHs were not detected in any of the 22 soil samples analyzed for Area 12. Of the landfill units with elevated TPH, autobody parts and waste oil were observed in only one (Unit 12-2) of the five units with elevated TPH concentrations during the excavation of test pits. All soil samples in this unit containing elevated TPH concentrations also contained residual MMAN concentrations above MTCA screening levels. Cleanup of soils for MMAN will remove TPH-containing soils above the MTCA screening level, therefore, it is unnecessary to establish cleanup levels for TPH in this unit of Area 12.

Area 38. Area 38 encompasses the buildings used for production and labeling of boxes and cartons used to package and ship products from the Site. Packaging materials were originally wooden boxes, which, over time, were replaced by paraffin-coated cardboard cartons. Both cardboard printing and paraffin coating activities occurred in this area. Water and/or solvents used to clean printing equipment in the box factory drained through a wooden trough from the building into a drywell located

approximately 15 feet south of the box factory. TPH concentrations above the MTCA screening level were detected in the three soil samples collected from the trough (two samples) and drywell (one sample). No cPAHs were detected in these samples although four of the ten samples had detection limits greater than 1 mg/kg due to sample matrix interference. Benzene and xylene, associated with historical use of solvents for cleaning printing equipment, were detected at concentrations well below MTCA screening levels in the surficial sample collected within the drywell. No BTEX were detected in deeper samples from the drywell.

A UST (containing diesel and/or Bunker C) was removed approximately 15 feet from the drywell in Area 38. All soils containing TPH above MTCA screening levels were removed in association with the UST removal (Hart Crowser, 1992b).

Residual paraffin was likely washed down the trough to the drywell from in the box factory, therefore the source of the TPH detected in Area 38 (limited to the trough and drywell) is most likely the paraffin. Because the analytical method for TPH (EPA Method 418.1) does not detect BTEX, and the detected TPH concentration (1,400 mg/kg) in the surficial sample from the drywell was substantially higher than the detected total BTEX concentration (1.9 mg/kg) in that sample, the TPH does not appear to be associated with the BTEX.

Regardless, all elevated TPH concentrations detected at the trough and drywell were limited to samples collected from 0 to 1.5 foot and were associated with concentrations of other constituents above MTCA screening levels, including arsenic, mercury, and lead. These other constituents were also detected at greater depths (2 to 4 feet) than TPH at these locations. Cleanup of soils for lead, arsenic, and mercury will remove all TPH-containing soils above the MTCA screening level, therefore, it is unnecessary to establish cleanup levels for TPH in this area.

Table I-5 provides data on Paraffin-Derived TPH concentrations in Areas 6, 12, and 38.

Table I-5 - TPH Data for Areas 6, 12, and 38 (Paraffin-Derived TPH)

Area ⁽¹⁾	Range of Concentrations in mg/kg	Detection Frequency	Arithmetic Mean in mg/kg	95 Percent UCL in mg/kg
TPH				
6	ND to 1,900	6/9	450	1,900
12	ND to 36,000	14/43	1,500	9,400
38	ND to 1,400	15/19	180	950

ND: Not detected. TPH detection limit of 20 mg/kg.

⁽¹⁾ Concentrations are summarized for samples above 15 feet because, where sampled, no detections of TPH or cPAH occurred below 15 feet in these areas.

Conclusions

TPH and cPAHs detected in several Site areas are associated with three different sources. The primary Site petroleum source, Bunker C, is confined to four areas (7, 8, 16, and 24) which have either undergone interim source removal or will be addressed subsequently. Mixed petroleum types were identified in five areas (5, 19, 26, 35, and 40) and one Area subunit (Unit 12-2). Interim source removal has been conducted in Areas 19, 35, and 40. Further action to address other constituents in Areas 5, 12-2, and 26 will concurrently address the remaining TPH concentrations above screening levels. Additionally, no further action, based on TPH concentrations, is proposed for the three areas with non-hazardous paraffin-derived TPH and no detected cPAHs (Areas 6, 12, and 38).

References for Appendix I

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J-3534-08

RTECS Database, 1994. Registry of Toxic Effects of Chemical Substances. National Institute for Occupational Safety and Health, Cincinnati, OH (CD-ROM version). Micromedex, Inc. Denver, CO (Edition Expires 4/30/94).

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APPENDIX II BUNKER C TPH/PAH COMPOSITION

As summarized in Appendix I, TPH on the Site has been detected in several forms. The composition of TPH determines its mobility and its potential to impact groundwater, as well as its toxicity. Bunker C fuel, associated primarily with the powerhouse and pipeline, is the predominant form of TPH on site (Appendix I). Bunker C and paraffin tend to adsorb tightly to soils and are not mobile. In support of this, TPH has not been detected in site groundwater (Appendix VI).

TPH composition also determines toxicity (Appendix IV). The toxicity of Bunker C, composed of heavier hydrocarbons, is associated primarily with cPAHs. No toxic fraction has been identified for paraffin. Because Bunker C is the predominant form of TPH found on site, its composition and how its composition effects mobility and toxicity is discussed in this Appendix.

Bunker C - Derived TPH

In general, Bunker C fuels, or heavy fuel oils, consist of a wide variety of formulations. The primary components of Bunker fuels are naphthenes, asphaltenes, saturated hydrocarbons, and aromatic hydrocarbons. Naphthenes, or cycloparaffins, are saturated cycloalkanes consisting primarily of 3 carbon-ring (cyclopropane), 4 carbon-ring (cyclobutane), 5 carbon-ring (cyclopentane), and 6 carbon-ring (cyclohexane) compounds. These ring structures may have a variety of saturated side chains. Asphaltenes are the heavier petroleum component of Bunker C and consist of primarily saturated longer chain compounds. Saturated hydrocarbons are represented by the long chain alkane compounds. Finally, the aromatics are primarily composed of PAHs. cPAHs have been determined to be the toxic fraction of Bunker C fuels.

Different formulations of Bunker C fuel oil are composed of varying concentrations of each of these components. A study by Bobra and Callaghan (1990) demonstrated the degree of variation in Bunker C compositions:

Component	% Content
Naphthenes	45
Asphaltenes	6 to 14
Saturates	15 to 24
Aromatics	25 to 55

Chromatograms of Bunker C product show that as much as 70 percent of its composition is hydrocarbons in the C-20 or higher range (refer to Figures II-1 and II-2).

Bunker C has been found in two forms on the Site. A viscous product is present in two areas (the Powerhouse - Area 24 and the Bunker C pipeline - Area 8), while a hardened tar-like residue was found at the bottom of Area 7 and Area 16 kettles.

Soils in Area 8, which contain elevated concentrations of Bunker C, have been removed to achieve the cPAH screening level of 1.0 mg/kg throughout the upper 15 feet of soil. Area 24 is scheduled for further action in 1994.

Kettle area soils are typically visibly stained and may have a hardened residue resulting from weathering of residual Bunker C. GC-FID fuel identification scans were performed on samples of the viscous and tar-like materials collected from these areas. Analysis of the chromatograms for these samples indicate that the viscous product from Areas 8 and 24 is unweathered Bunker C, and the hardened product from Areas 7 and 16 is weathered Bunker C. Weathered products typically do not show lighter-end hydrocarbons that show up in the unweathered samples. Lighter-end hydrocarbons have a greater tendency than heavier compounds to volatilize, degrade, or mobilize when exposed to the environment. Chromatograms for one weathered sample (16-SS-502) and one unweathered sample (16-SS-503) are included on Figures II-1 and II-2, respectively.

The limited mobility of weathered Bunker C was confirmed by subsurface explorations in Areas 7 and 16. TPH detections in explorations within the kettles correspond to a distribution of a thin layer (typically 1 to 6 inches) of hydrocarbons across the bottom of the kettles. Data from Area 7 subsurface explorations indicate that elevated TPH concentrations are vertically bounded to the upper 3 feet of material. Elevated TPH concentrations in Area 16 are vertically bounded to the upper 1 foot of material.

Bunker C product from the pipeline (Area 8) exhibits greater mobility than the weathered product. The practice of heating the fuel prior to pumping it through the pipeline may have increased mobility of Bunker C from the pipeline. Leakage from pipeline joints over time, pressurizing the pipe to improve transport, and the large volumes of product transported, all contributed to the mobilization of Bunker C in this area. Bunker C product from the pipeline was detected up to 35 feet below the ground surface. However, the pipeline has not been used since the mid-1960s. Interim

source removal in Area 8 has further controlled the TPH source in this area and also achieved cPAH screening levels. Based on soil leachability testing (TCLP) performed on soil samples collected from Area 8 (Appendix VI), residual TPH present in this area at the conclusion of interim source removal is not a possible TPH source to groundwater.

Bunker C-Derived cPAH

Locations where TPH was detected were evaluated for PAH composition. Soil samples from Area 8 analyzed for PAHs indicate the presence of 12 of 16 PAHs analyzed. Characterization of PAHs was performed on 52 soil samples from Area 8 with cPAHs detected in 31 of the 52 samples.

Site-wide soil testing demonstrated that the seven cPAHs were present in different areas. Chrysene is the predominant cPAH appearing in 40 out of 121 soil samples tested for PAHs, with a maximum concentration of 14 mg/kg. However, chrysene is the least potent cPAH, exhibiting a relative potency of 0.1 percent that of benzo(a)pyrene (BAP; EPA, 1993) (Appendix IV). Benzo(b)fluoranthene and BAP were the second and third most frequently detected cPAHs, appearing in 27/121 and 24/121 soil samples, respectively. The concentrations of these compounds were lower than chrysene, with maximum concentrations of only 7.0 mg/kg for benzo(b)fluoranthene and 4.8 mg/kg for BAP. Benzo(b)fluoranthene exhibits a relative potency 10 percent that of BAP. Table II-1 summarizes the relative detection frequencies of cPAHs.

Table II-1 - Concentrations and Occurrence of Individual cPAHs

cPAH ⁽¹⁾	Detection Frequency	Maximum Concentration in mg/kg
Benzo(a)anthracene	22/121	8.6
Benzo(a)pyrene	24/121	4.8
Benzo(b)fluoranthene	27/121	7.0
Benzo(k)fluoranthene	17/121	2.3
Chrysene	40/121	14.0
Dibenzo(a,h)anthracene	8/121	0.5
Indeno(1,2,3-c,d)pyrene	19/121	1.6
Total cPAHs	48/121	37.0

Note:

⁽¹⁾ These seven PAHs are considered probable human carcinogens by EPA (IRIS, 1994).

Conclusions

Bunker C detected on the Site was found in two forms, a viscous product associated with the powerhouse and pipeline, and weathered Bunker C found in the Area 7 and Area 16 kettles. Interim source removal has removed the majority of Bunker C product associated with the pipeline. Weathered Bunker C was confined to surficial soils in Areas 7 and 16.

Based on soil leachability testing, residual TPH is low mobility and does not represent a TPH source to groundwater.

Although all seven cPAHs were detected in various site samples with elevated Bunker C, chrysene, one of the least potent of the cPAHs, exhibiting a potency of 0.1 percent of that of BAP, was the predominant cPAH detected on the Site.

Thus, the Bunker C at the Site is comprised of predominantly less mobile and less toxic cPAHs (Appendix IV).

References for Appendix II

Bobra, M., and S. Callaghan, 1990. A Catalogue of Crude Oil and Oil Product Properties. Environment Canada Environment Protection Directorate. River Road Environmental Technology Centre, Ottawa. KIA OH3, September, 1990.

EPA, 1993. Provisional Guidance for Quantitative Risk Assessment of Polycyclic Aromatic Hydrocarbons, Washington DC, EPA/600/R-93/089.

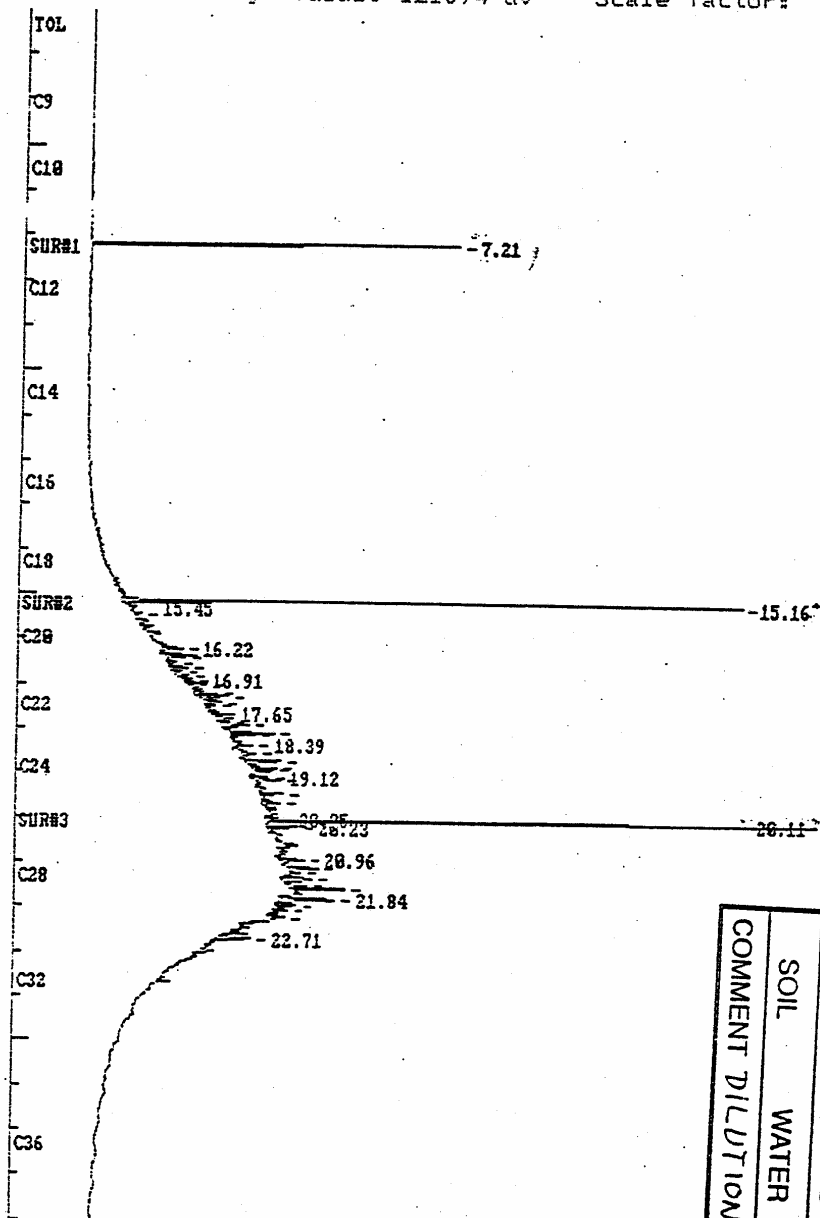
EPA, 1994. IRIS Integrated Risk Information System, Database 1994.

Attachments:

- Figure II-1 - Chromatogram for Sample 16-SS-502
- Figure II-2 - Chromatogram for Sample 16-SS-503
- Figure II-3 - Chromatogram for Sample 7-SS-507
- Figure II-4 - Chromatogram for Sample 7-SS-508

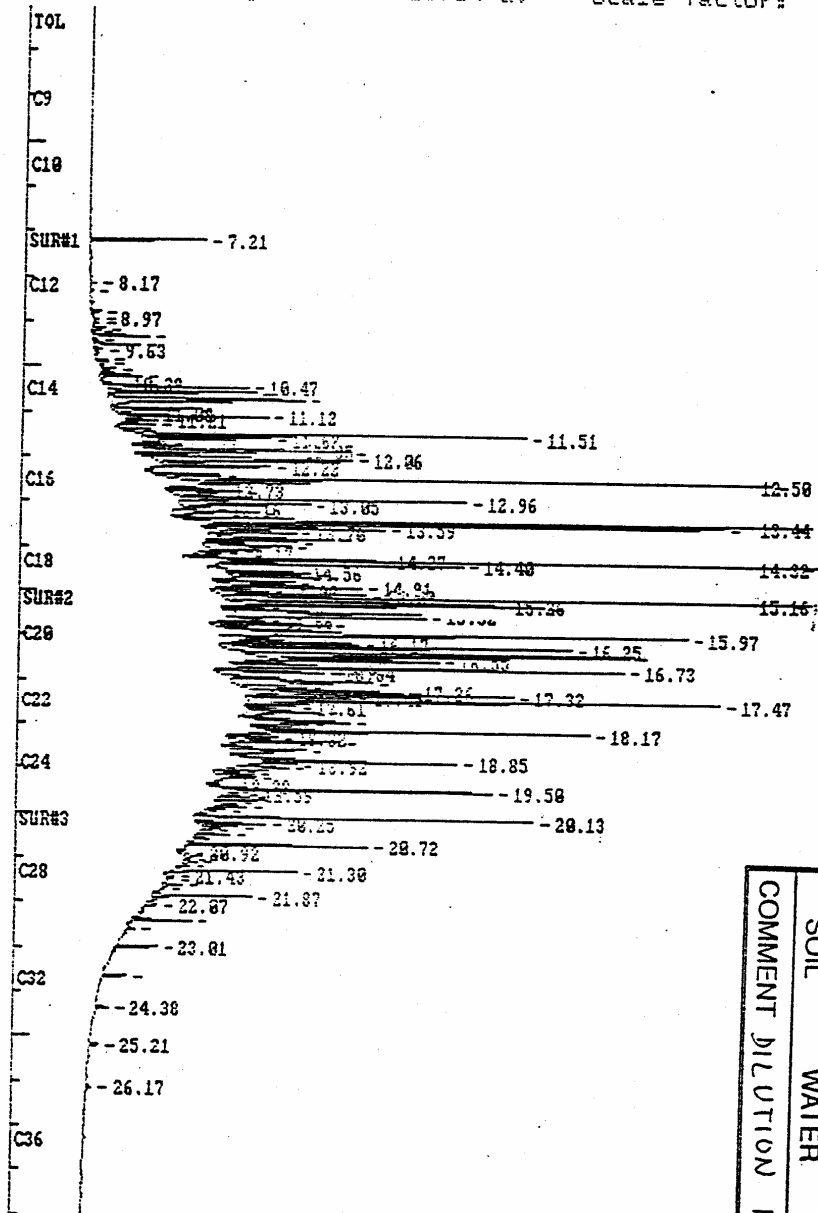
tphtph2.new

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SAMPLE#	16-SS-502
SOIL	WATER Product
COMMENT	DILUTION 1:100

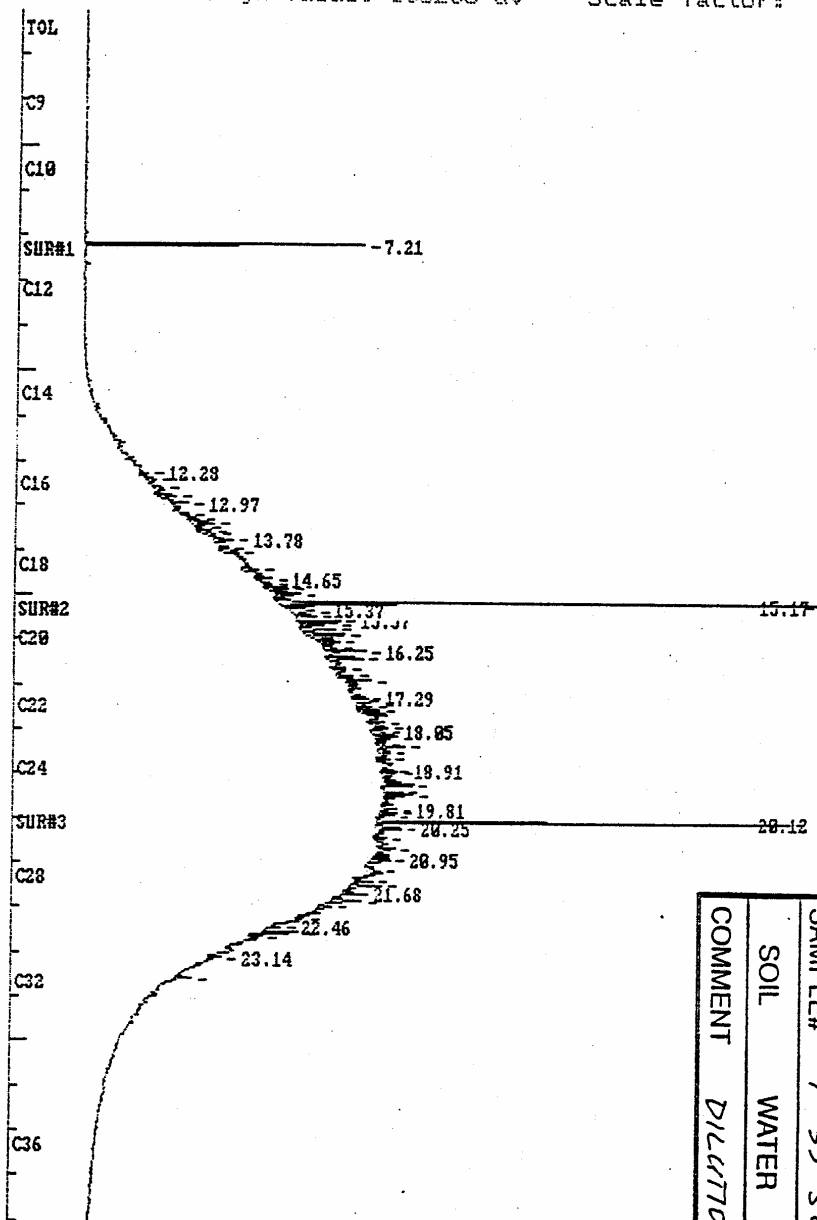
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HART CROWSEY LABORATORY
JOB# 3534-00
SAMPLE# 16-55-503
SOIL WATER Product
COMMENT DILUTION 1:100

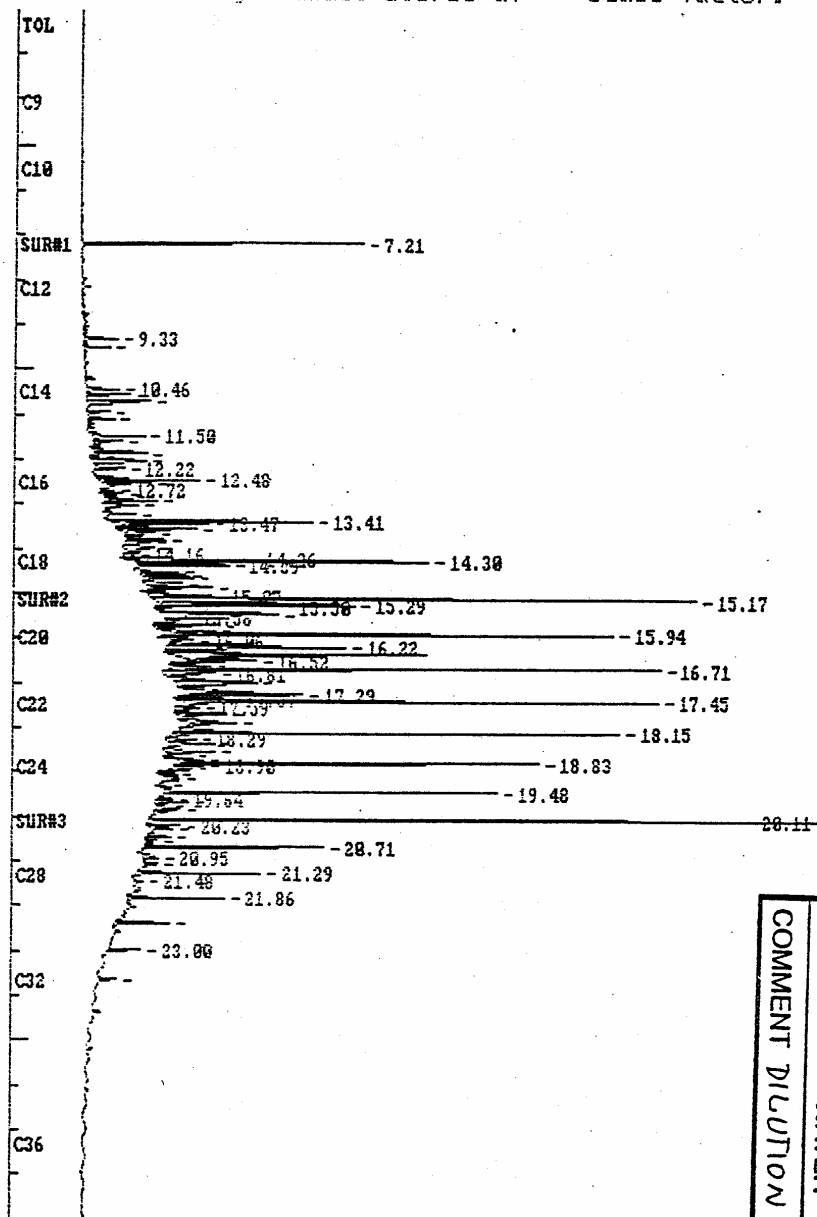
Figure II-2

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 Value: -97 uv High Value: 158256 uv Scale factor: 1.0



HART CROWSEY LABORATORY	
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SAMPLE#	7-SS-507
SOIL	WATER product
COMMENT	DILUTION 1:100

File = E:SUR21.PTS Printed on 07-17-1992 at 09:20:09
 Start time: 2.00 min. Stop time: 29.00 min. Offset: 0 mv.
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HART CROWSEY LABORATORY
JOB# 3534-00
SAMPLE# 7-SS-SO8
SOIL WATER Product
COMMENT DILUTION 1:100

APPENDIX III

DEVELOPMENT OF cPAH SOIL CLEANUP LEVELS FOR DESIGNATED LAND USES AT THE SITE

Soils with residual TPH/cPAH are contained within areas where the future land use may be either residential or recreational (although TPH/cPAH has not been detected in the zoned industrial areas of the Site, an industrial cleanup level has been developed in this appendix). This appendix describes the rationale and procedures used to develop cleanup levels for cPAH that will be protective of human health for these land uses.

Basis for Exposure Assumptions

Land Use. Following Site development, the non-industrial areas will include residential and recreational use areas. Recreational land use will include both a golf course and open space.

cPAH cleanup levels were generated for an industrial scenario and three exposure scenarios: golf course, open space, and residential. Note, however, that current development plans do not include residential areas where cPAH has been detected. Different exposure assumptions are applied in each scenario to account for the most likely individuals and activities producing the potential for exposure.

During golf course development, residual constituents in soil will be covered by one to two feet of topsoil in order to support course turf against the extremely rapid drainage of the native soils (Cummock, 1993; D'Aboy, 1993; Griswold, 1993). The only potential for exposure to the subsoils beneath the turf and imported topsoil would be infrequent activities requiring maintenance workers to dig through the barrier into the subsoils. Golfers and other visitors (e.g., trespassers) would not have contact with the subsoils. The cPAH cleanup level for golf course land use is derived from assumptions appropriate to a golf course maintenance worker.

In open space or green belt areas, residual soils may be available for direct contact, but not through activities typically associated with soil contact such as gardening, landscaping, or incidental ingestion by very young children (i.e., children less than six years old, who are typically assumed to incur the greatest levels of intake through soil contact, will be less likely to roam unattended through open space areas). Older children may represent the most likely, potentially exposed subpopulation, since they may roam through open space areas more freely than younger children. The DNT cleanup level for open space land use is intended to protect all children visiting open space areas, so the cleanup level was calculated using

parameters for a younger (0-6 year old) child in a recreational setting. This will be conservative for the older child.

The cPAH cleanup level for residential land use is intended to protect the younger (0-6 year old) child as a sensitive receptor, so the cleanup level was calculated using parameters typical for a child resident. Note again that cPAH has not been detected in areas currently planned for residential development.

The cPAH cleanup level for industrial land use is intended to protect an adult worker assumed to have regular and frequent (daily, occupational) contact with Site soils.

Ranges in risk-based cleanup levels. Recent risk assessment policy guidance (EPA 1992a) recommends development of risk ranges to describe potential risks from constituents at hazardous waste sites, and to inform risk management decisions for those sites. Risk ranges describe and account for uncertainty in risk assessment methods, and provide perspective on the upper-bound estimates of risk conventionally presented in risk assessments. Risk management is considered appropriate when predicted carcinogenic risks are in the range between one-in-one-million (10^{-6}) and one-in-ten-thousand (10^{-4}). In general, management of risks below the one-in-one-million threshold is unwarranted, whereas abatement of risks above the one-in-ten-thousand level is (usually) considered unnecessary.

Similarly, risk-based cleanup levels may be derived by rearranging equations used to estimate risk, and solving the equations for the concentration term associated with a pre-specified risk threshold (e.g., one-in-one-million). The concentration term is then regarded as the cleanup level associated with that threshold. Cleanup levels derived from rearranged risk algorithms are subject to the same types and degrees of uncertainty that apply to estimates of risk. Therefore, it is appropriate to generate a range of cleanup levels for consideration in the risk management process. The ranges of cleanup levels established in this document are based on a risk threshold between 10^{-6} and 10^{-5} for residential, open space, and golf course land use, and 10^{-5} and 10^{-4} for industrial land use.

Derivation of the Cleanup Levels

Soil cleanup levels for BAP are based on protection against potential carcinogenic effects. The carcinogenic potential of cPAH is conservatively represented by benzo(a)pyrene (BAP), the most potent cPAH (see below).

Two exposure routes are considered in the development of cleanup levels for cPAH: soil ingestion and dermal contact with soil. The cleanup levels

are calculated using equation 1. This equation is developed from exposure equations provided in Exhibits 6-14 and 6-15 in RAGS (EPA, 1989) by simultaneously solving the equations for the concentration in soil.

$$CS = \frac{\text{Risk} \times BW \times AT}{CPF \times CF \times FI \times EF \times ED \times [(IR \times ABS_i) + (SA \times AF \times ABS_d)]} \quad (1)$$

Tables 1 and 2 define the parameters in equation 1, and provide the values and references used for each land use. Values are based on estimates of central tendency for most parameters such that exposure, averaged over a lifetime, will produce an incrementally increased risk of cancer equal to the risk management threshold given as the "risk" parameter.

Table 1: Parameters Used to Calculate Cleanup Levels.

PARAMETER	DESCRIPTION	ECT							
		RES	a	OS	b	GC	c	IND	d
Risk	Acceptable risk level (unitless)	e	←	1E-5 to 1E-6	→			1E-4 to 1E-5	
BW	Body weight (kg)	f	15	15		70		70	
AT	Averaging time – carcinogens (days)	f	25550	25550		25550		25550	
CF	Conversion factor (mg/kg)	g	1E-6	1E-6		1E-6		1E-6	
FI	Frequency of intake (percent)	h	100	100		100		100	
EF	Exposure frequency (days/year)		275	i	52	j	36	k	250
ED	Exposure duration (years)		3	l	3	l	9	m	9
IR	Soil ingestion rate (mg/day)		63	n	63	n	26	o	26
SA	Skin surface area (cm ²)	p	800		800		2000		2000
AF	Soil to skin adherence factor (mg/cm ²)	p	0.2		0.2		0.2		0.2

NOTES

- RES represents residential land use. The most exposed individual is a child.
- OS represents open space land use. The most exposed individual is a child.
- GC represents golf course land use. The most exposed individual is an adult.
- IND represents industrial land use. The most exposed individual is an adult.
- Two iterations were completed for RES, OS and GC: one at a risk threshold of 10⁻⁵, and one at 10⁻⁶. For IND, iterations were at 10⁻⁴ and 10⁻⁵.
- From EPA 1991a.
- Converts kg soil to mg soil.
- Set at the maximum value to be conservative.
- From EPA Region X, 1991.
- ASARCO. 1993.
- Cupit, 1993; D'Aboy, 1993; McCarthy, 1993.
- Use 3 as the mid-point of a 0-6 year uniform distribution.
- From RAGS (EPA, 1989).
- Thompson and Burmaster 1991.
- From D.O.E. 1993.
- From EPA 1992b.

Table 2: cPAH-specific Parameters Used to Calculate Cleanup Levels.

PARAMETER	DESCRIPTION	cPAH	
CPF	Cancer potency factor (mg/kg-day) ⁻¹	7.30	a
ABSi	Gastrointestinal absorption factor (percent)	100	
ABSd	Dermal absorption factor (percent)	2.3	b
NOTES	a. From Huether (1993). b. EPA Region 10, February, 1991 as cited in Eagle Harbor Revised Risk Assessment, 1991.		

The U.S. EPA has acknowledged the use of certain average exposure assumptions in managing potential risks from carcinogens (EPA, 1991b). The basis of this recommendation is that protection against carcinogenic effects relies on a model of long-term exposure. Long-term exposure is best approximated using average values rather than extreme values, since the latter have "no consistent relationship" with long-term exposure. In order to account for uncertainty in some exposure parameters, upper-bound values are used for these parameters to assure a conservative approach to human health protection. Several sources of uncertainty for which conservatism is maintained are discussed below.

cPAH Potency. The carcinogenic potency of cPAH as a class is conservatively represented by the toxicity of benzo(a)pyrene (BAP). However, of the seven PAHs considered to be carcinogenic, BAP is the most potent. One cPAH is as potent as BAP; the other five are substantially less potent (10 to 1,000 times less potent). Because of this, toxicity equivalence factors (TEFs) may be applied in risk assessments when specific cPAHs are identified (EPA 1993).

The carcinogenic potency factor for BAP was used to develop cleanup levels at the Site. However, the predominant cPAH at the Site is chrysene, which is one-thousand times less potent than BAP. Therefore, use of the BAP potency factor is very conservative.

Fractional Intake from Specific Source Areas. The FI term as provided in Risk Assessment Guidance for Superfund (RAGS; EPA 1989) accounts for the fractional amount of soil that may be ingested on a daily basis from different sources. As applied in the Site risk assessment, the FI term describes the frequency of soil contact by an individual at the golf course or open space areas (FI in residential and industrial scenarios was assumed to be 100 %). The term accounts for the fact that only a portion of the surface area designated for golf course and open space use overlies Site areas with residual constituents in the soil. Furthermore, exposure at the

golf course will be limited to maintenance workers, who occasionally may be required to excavate soils to a depth penetrating the 1-2 foot barrier of amended topsoil that will overlie native soils. This barrier will prevent exposure to individuals walking over the golf course.

In the Site risk assessment, exposure to subsurface soils at the golf course or surface soils in open space areas was assumed to be random, occurring with a frequency of contact equal to the percentage of total land use surface area represented by a given Site area (e.g., the surface area of Area 16 equals 2% of the total, planned open space area; therefore, the probability of contacting surface soils in Area 16 during an open space visit is assumed to be 2%).

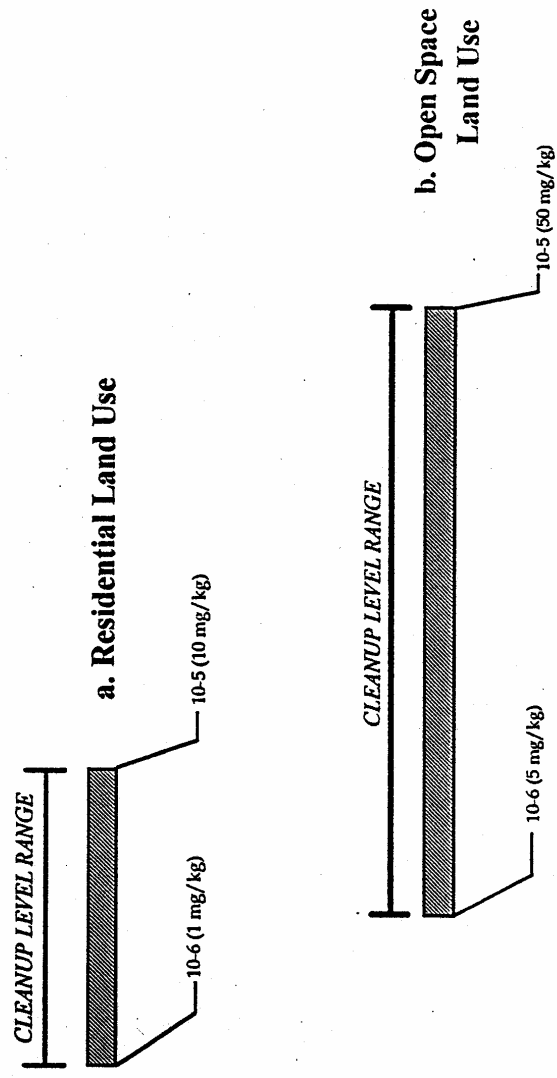
However, to derive cleanup levels for the Site, FI is assumed equal to 100% for both the open space and golf course scenarios. This is conservative, since it is highly unlikely that an individual will visit the same location (or all locations) during each visit, or that each excavation by a golf course worker will occur in the same place.

Using the parameters provided in the tables, the following cPAH cleanup level ranges are calculated for each land use:

- 1-10 mg/kg for residential land use;
- 5-50 mg/kg for open space land use;
- 20-220 mg/kg for golf course land use; and
- 30-300 mg/kg for industrial land use.

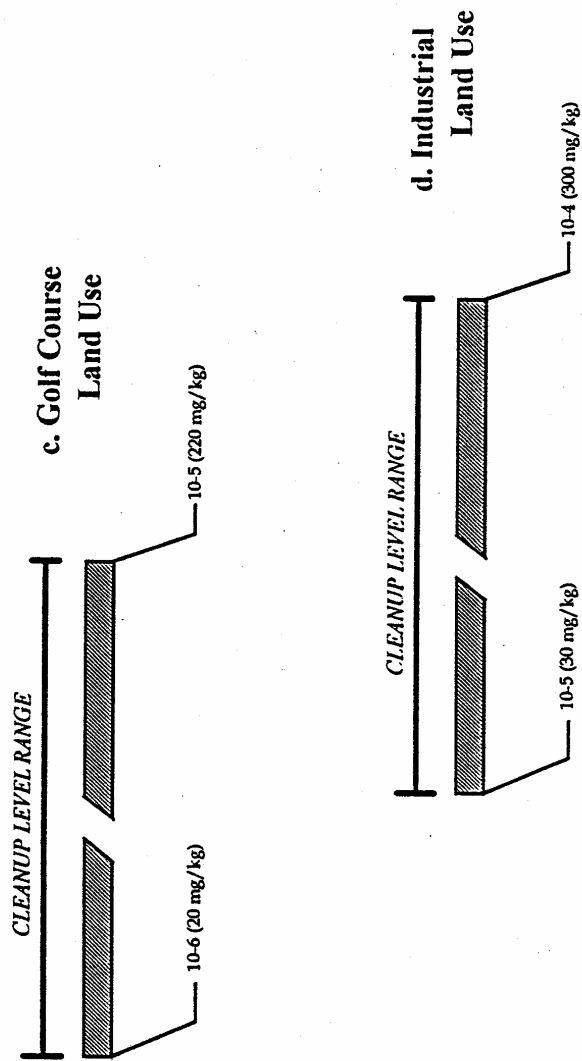
The ranges for residential, open space and golf course land use correspond to a risk threshold range between 10^{-6} and 10^{-5} ; the range for industrial land use corresponds to a risk threshold range between 10^{-5} and 10^{-4} . These ranges are depicted graphically in Figure 1.

FIGURE 1: CLEANUP LEVEL RANGES FOR cPAH¹



¹Scaling is relative.

FIGURE 1: CLEANUP LEVEL RANGES FOR cPAH (continued)



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APPENDIX IV HUMAN HEALTH TOXICITY OF TPH/PAHS

Carcinogenic Polycyclic Aromatic Hydrocarbons (cPAHs) are the most toxic component of Bunker C petroleum hydrocarbons. The MTCA regulation states that the cleanup level for TPH can be based upon the toxic fraction of the petroleum compound (WAC 173-340-740 (3)(a)(ii)(B)). As summarized in Appendix II, the most commonly detected cPAH was chrysene, one of the least potent of the cPAHs. Few studies are available concerning the toxicity of specific petroleum products; therefore, the following literature has been reviewed and relevant information compiled in the following section.

Bunker C Toxicity

Acute Toxicity. The American Petroleum Institute (API) commissioned Elars Bioresearch to study the acute toxicity of a variety of fuel petroleums (Beck et al., 1984). Four types of Bunker C fuel oils were studied. They were identified by specific gravity (sp) and sulfur content (%S): sp 0.99/2.7%S; sp 0.95/0.8%S; sp 0.92/0.2%S; and sp 1.04/1.2%S. Tests were performed to determine acute dermal and oral toxicity. Oral exposure to the Bunker C fuels with specific gravities of less than 1.0 demonstrated little toxicity with no increase in mortality associated with dosages up to 25 ml/kg body weight. The final Bunker C fuel, sp 1.04/1.2 %S, however, demonstrated measurable toxicity with an oral LD₅₀ of 5 ml/kg body weight. Similar results were reported concerning dermal toxicity. These experiments illustrate the variability of toxicity associated with different formulations of Bunker C.

Acute Toxicity of Bunker C Components. Bunker C fuel oil is composed primarily of naphthenes, asphaltenes, saturated hydrocarbons, and aromatics (PAHs) (see Appendix II). cPAHs, the toxic component of Bunker C fuel oil, will be addressed separately.

Saturates, i.e., the saturated hydrocarbon chains with 9 or more carbons, have relatively little toxicity data. None of the long-chain (C-15 or greater) hydrocarbons are believed to be teratogenic, mutagenic, or carcinogenic (Clayton and Clayton, 1982). Extremely long chain compounds such as N-Pentadecane (C-15), 1-Octadecanol (C-18), and 1-Eicosanol (C-20) are considered relatively non-toxic with LD₅₀s greater than 15,000 mg/kg.

Asphaltenes also are considered to be relatively non-toxic. The International Agency for Research on Cancer (IARC) has evaluated the

data for asphaltenes and determined the data to be insufficient to classify these compounds as carcinogens (IARC, 1989). These compounds have also not been found to be mutagenic in mouse skin models (HSDB, 1994). In general, these compounds have little or no toxicity associated with them, even among road workers who used asphalt as a chewing-gum material (HSDB, 1994).

As with the other Bunker C components, naphthenes have very limited acute toxicity data. These data suggest that naphthenes are relatively non-toxic as well. Toxicity data on cyclopropanes, cyclobutanes, and cyclopentanes describe these compounds to only be toxic as simple asphixiants, although there is some evidence that cyclopropane may be carcinogenic (Lewis, 1992). Cyclohexane and ethylcyclohexane were demonstrated to have LD₅₀s of 30,000 and 64,000 mg/kg, respectively. These data suggest that the longer chain naphthenes will be relatively non-toxic compared with other components of Bunker C.

Carcinogenicity. The IARC has reviewed information concerning the carcinogenicity of a variety of petroleum fuels (IARC, 1989). Bunker C has not been demonstrated to be mutagenic in either bacterial or whole cell models. Bunker C has both positive and negative results in tumorigenic studies. Human epidemiology data are hard to interpret because of mixed exposures. As a result, the IARC has given Bunker C fuel a Group 2B ranking, possible human carcinogen. No ranking by the EPA is available at this time.

Bingham et al. (1980) linked the carcinogenicity of Bunker C with the fuel's PAH content. C3H mice were given dermal applications of 20 mg Bunker C twice weekly for an unspecified period of time (at least 59 weeks). Bunker C fuel containing 0.01 percent benzo(a)pyrene resulted in 2 out of 19 mice developing tumors over 59 weeks. In mice treated with Bunker C fuel containing 0.16 percent benzo(a)pyrene, 21 out of 25 developed tumors over 59 weeks (of which 12 were malignant). This study indicates that the carcinogenicity of Bunker C is largely dependent upon the PAH content of the particular fuel.

cPAH Toxicity

Carcinogenicity. Chrysene, benzo(a)anthracene, benzo(b)fluoranthene, benzo(k)fluoranthene, dibenzo(a,h)anthracene, indeno(1,2,3-c,d)pyrene, and benzo(a)pyrene have all been determined to be complete carcinogens in animals by multiple routes of exposure. These seven cPAHs have been classified by the EPA as Group B2, probable human carcinogens (IRIS, 1994).

Benzo(a)pyrene is typically used as the representative PAH based on the availability of data. Neal and Rigdon (1967) reported a dose-related incidence of forestomach tumors in mice orally exposed to benzo(a)pyrene. An additional study by Brune et al. (1981) also demonstrated a dose-related incidence of tumors in sprague-Dawley rats. Slope factors for benzo(a)pyrene have been calculated using both a linear multi-stage model of carcinogenesis and a two-stage model. Four slopes, from 4.5 to 11.7, have been calculated. The EPA has presently established an oral carcinogenic slope factor of $7.3 \text{ (mg/kg-day)}^{-1}$ based on the geometric mean of these four previous slope factors (IRIS, 1994).

Relative Potencies of cPAHs. Benzo(a)pyrene (BAP) has been determined to be one of the most potent carcinogens of the cPAHs (EPA, 1986). Clement Associates (1988) used the two-staged carcinogenic model to develop potency estimates for various cPAHs that have demonstrated lesser carcinogenic potential than BAP. Quantitative risk estimates for mixtures of PAHs have often assumed that all cPAHs are as toxic as BAP, and that the carcinogenic effect of the mixture can be estimated by the sum of the effects of each individual cPAH. However, it has been documented that five of the seven cPAHs are less carcinogenic in animal studies than BAP (the toxicity of dibenzo(a,h)anthracene is assumed to be equal to BAP). Thus, assuming all cPAHs to be as toxic as BAP can result in an overestimation of risk (EPA, 1993a).

In 1993, based on the EPA's Office of Health and Environmental Assessment (OHEA) review of the Clement Associates (1988) report, OHEA issued provisional guidance for quantitative risk assessment of PAHs (EPA, 1993a), which is considered interim guidance. However, a recent memorandum originating from EPA Region 10 (EPA, 1993b) indicates that all the EPA regions agree that the new PAH policy would be formally adopted by EPA in the near future and that all the regions would use the policy as interim guidance for risk assessment of PAH compounds. Included in this guidance is an order of magnitude ranking of relative potency values for the individual PAHs that are recommended in order to provide a consistent approach in risk assessment.

Assessment of the risk of mixtures, using the relative potency approach, involves the following steps:

- ▶ Analytical determination of cPAHs;
- ▶ Multiplication of sample concentrations by their relative potencies to express concentration in terms of BAP equivalents, or relative potency concentrations (RPC);

- ▶ Summation of the RPCs to obtain total BAP equivalents in the sample;
- ▶ Determination of human exposure (expressed in terms of BAP equivalents); and
- ▶ Combining exposure with cancer potency information on BAP to estimate the cancer risk associated with exposure to the PAH mixture.

Table IV-1 summarizes the relative potencies for cPAHs (as presented in EPA, 1993a) detected at the Site.

Table IV-1 - Relative Potencies for cPAHs

cPAH	Relative Potency Factors
Benzo(a)Anthracene	0.1
Benzo(a)Pyrene	1.0
Benzo(b)Fluoranthene	0.1
Benzo(k)Fluoranthene	0.01
Chrysene	0.001
Dibenzo(a,h)Anthracene	1.0
Indeno(1,2,3c,d)Pyrene	0.1

As discussed in Appendix II, chrysene—the least potent of the seven cPAHs—is also the most prevalent cPAH at the Site. Therefore, sample cPAH results from Areas 7, 8, and 16 were normalized to total BAP equivalents using RPFs in order to more accurately reflect the relative potency of the cPAHs associated with the Bunker C detected on the Site. Normalized cPAH results were used to derive a cleanup level for TPH based on a correlation between TPH and cPAH concentrations (Appendix V).

Conclusions

The toxic fraction of the Bunker C product on Site is related to cPAHs. Much of the remaining content of Bunker C fuels is relatively non-toxic because it is composed of non-aromatic straight chain hydrocarbons. Because chrysene is the most prevalent but least potent of the cPAHs present at the site, it is appropriate to use EPA's interim relative potency

factors to estimate the potential cancer risk associated with exposure to these substances at the Site.

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APPENDIX V BUNKER C TPH CLEANUP LEVEL

In order to determine a cleanup level for Bunker C TPH detected on the Site, and recognizing that the risk posed by Bunker C is largely attributable to its cPAH components, correlation analyses were performed to assess the statistical relationship between cPAH and TPH concentrations. A correlation analysis was performed to determine an appropriate Site-wide cleanup level for Bunker C-derived TPH.

Regression Analysis to Determine Site-Wide Bunker C TPH Cleanup Level

An evaluation of the correlation between TPH and cPAHs was performed on samples collected from areas known to contain elevated concentrations of Bunker C. Regression analysis was performed on data collected from Areas 7, 8, and 16 combined. Data were combined from all Bunker C areas because: 1) there was limited cPAH data for area-specific correlations; 2) no significant differences were observed between area-specific correlations; and 3) the same product has been demonstrated to occur in all three areas (see Appendix II).

Cumulative total cPAH concentrations were assessed in the regression analyses. Sample cPAH results were normalized to total BAP equivalents in order to more accurately reflect the potency of individual cPAHs (see Appendix IV). The TPH concentrations associated with normalized cPAH concentrations of 1.0 and 10.0 mg/kg, the range of acceptable residential cleanup levels based on the toxicity of BAP, were calculated for the 95 percent upper confidence level.

Based on the regression analysis ($r^2=0.52$), normalized total cPAH concentrations of 1.0 and 10.0 mg/kg are equivalent to TPH residential cleanup levels of 3,100 to 27,000 mg/kg at the 95 percent confidence level (see Figure V-1).

Conclusions

Results indicate that cleanup levels of 3,100 to 27,000 mg/kg for Bunker C-derived TPH will achieve the cleanup goal of 1.0 to 10.0 mg/kg for cPAHs (residential land use) in Areas 7, 8, and 16. Normalized cPAH data accurately reflect the toxicity associated with the cPAHs detected on Site (see Appendix IV) and represent an accurate method for deriving a Bunker C cleanup level.

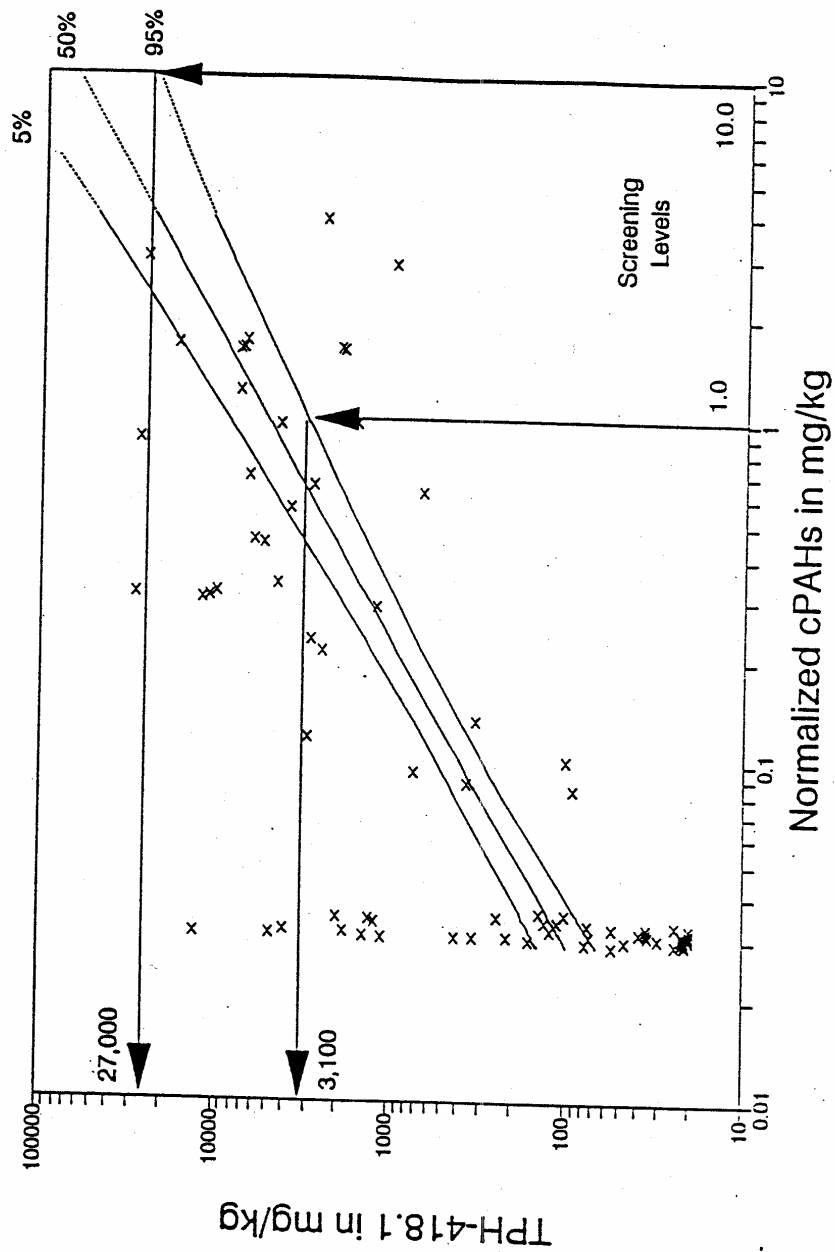
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Figure V-1

Correlation Between cPAHs and TPH-418.1
Bunker C Areas 7, 8, and 16

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Correlation Between cPAHs and TPH-418.1 Bunker C Areas 7, 8, and 16



**APPENDIX VI
GROUNDWATER, SURFACE WATER, AND LEACHABILITY DATA
FOR TPH AND cPAHs**

Groundwater Data

TPH Data for Groundwater. Total petroleum hydrocarbons (TPH; WTPH 418.1 analysis) have not been detected in any groundwater sample collected during the four rounds of RI groundwater sampling. The TPH data for groundwater are presented in Table VI-1.

Non-Carcinogenic PAH Data for Groundwater. Of the 129 groundwater samples collected during four rounds of RI groundwater sampling, no sample had confirmed detections of any PAH above the MTCA drinking water screening levels for non-carcinogenic (e.g., chronic toxicity) effects.

cPAH Data for Groundwater. One of the 129 groundwater samples collected during four rounds of RI groundwater sampling had an unconfirmed detection of total cPAHs above the 0.0001 mg/L MTCA screening level for total cPAHs (Table VI-2). During the September 1992 sampling round, one of two samples collected from monitoring well MW-8 had a reported total cPAH concentration of 0.0016 mg/L. However, this result was not confirmed by the field duplicate sample collected concurrently from MW-8, which had only a single cPAH (chrysene) detected at the detection limit (0.00001 mg/L). The discrepancy in results between this set of duplicate samples suggests possible sample contamination during sample handling in the field or laboratory. This is further supported by the lack of cPAH detections in groundwater samples or field duplicates from MW-8 in any of the other groundwater sampling rounds, either before or after the September 1992 sampling round. Detected total cPAH concentrations also have not exceeded the 0.0001 mg/L screening level in any other groundwater samples collected during the RI. Based on these data, the single unconfirmed detection of cPAHs in MW-8 above the screening level is not considered representative of groundwater quality at this location or elsewhere at the Site.

Chrysene has been detected inconsistently in groundwater samples from 11 monitoring wells (excluding the September 1992 sample from MW-8) at concentrations marginally above the MTCA Method B screening level of 0.000012 mg/L (Table VI-2). As discussed in Appendix IV, the individual cPAH screening levels are based on benzo(a)pyrene toxicity. Because benzo(a)pyrene is a more potent carcinogen than chrysene (by three orders of magnitude), the individual cPAH screening level is highly conservative for chrysene, which is the least potent of the seven cPAHs.

The chrysene detections occur infrequently in different monitoring wells, including well MW-14 located along the eastern (hydraulically upgradient) edge of the Site. The detected concentrations are very low, ranging from 0.00002 to 0.0001 mg/L, with an average of 0.00003 mg/L relative to the detection limit of 0.00001 mg/L. Furthermore, chrysene is not detected consistently at a given well over time (detected in only one of the 11 wells in more than one of the four sampling rounds). Statistical testing (a Fisher's Exact Test) indicates that the proportion of chrysene detections in on-site monitoring wells (16/129) is not significantly different (at $p = 0.05$; 95% confidence level) than the proportion of detections in background wells (0/12).

Benzo(b)fluoranthene and dibenzo(a,h)anthracene were also each detected in one groundwater sample (other than the September 1992 sample from MW-8) at concentrations marginally above the individual cPAH screening level (Table VI-2).

It should be noted that the RI analyses' very low-level detection limits for individual cPAHs in water (0.00001 mg/L) are essentially the same as the screening level for individual cPAHs (0.000012 mg/L). As a result, almost any detection of an individual cPAH in groundwater is above the screening level. Furthermore, the individual cPAH screening levels are below practical quantitation limits (PQLs) of 0.0002 to 0.002 mg/L as defined by Ecology (Ecology, 1993).

In any event, all samples in which an individual cPAH was detected (other than the September 1992 sample from MW-8), had a total cPAH concentration at or below the 0.0001 mg/L screening level for total cPAHs.

The screening levels for individual cPAHs are highly conservative since they are based on benzo(a)pyrene toxicity (discussed in Appendix IV). Chrysene, not benzo(a)pyrene, is the only cPAH detected in more than one groundwater sample collected from the Site (excluding anomalous September 1992 sample from MW-8). Because a screening level based on chrysene toxicity would be 0.012 mg/L (0.000012 mg/L/0.001 Relative Potency Factor [RPF]; refer to Appendix IV), the MTCA drinking water screening level for total cPAHs (0.0001 mg/L) is protective of human health and the environment at the Site.

Surface Water Data

TPH and ncPAH Data for Surface Water. No TPH or non-carcinogenic PAHs were detected above MTCA screening levels in any of the four rounds of RI surface water sampling.

cPAH Data for Surface Water. cPAHs were detected at a concentration above the most stringent surface water screening level in one surface water sample; however, the data indicate that the single exceedence was the result of elevated sample turbidity created during sampling.

In the December 1992 sampling round, low concentrations of cPAHs were detected in the surface water sample from sampling location SW-1 near the mouth of Sequalitchew Creek (Table VI-2). Six of seven individual cPAH concentrations (0.00006 to 0.00023 mg/L) were above MTCA screening levels (0.000031 mg/L based on benzo(a)pyrene toxicity). Because seasonally low water conditions occurred at SW-1 during the December 1992 sampling round, greater than usual sediment was stirred up during sampling, resulting in elevated total suspended solids (TSS) in the sample. The TSS value in this sample was 160 mg/L, an order of magnitude higher than all other TSS values measured from the SW-1 location. Because cPAHs have relatively low solubilities, the low level cPAH detections are likely related to the higher levels of particulate matter (TSS) in the sample.

No cPAHs were detected in any other surface water sample from the four rounds of sampling, indicating that the single detection is not representative of surface water quality at the Site.

Leachability Data

The lack of petroleum compounds (TPH and PAH) detected in groundwater or surface water is consistent with the low degree of leachability measured during toxicity characteristics leaching procedure (TCLP) testing for these compounds in Site soils.

Nine soil samples collected from Area 8 (Bunker C-derived) were tested for TPH leachability using the TCLP test (EPA Methods 1311/418.1). The TPH concentrations in the nine soil samples submitted for TCLP analysis ranged from 800 to 19,000 mg/kg. In addition, one of the samples was tested for TCLP PAHs. The TCLP test employs a much more rigorous leaching procedure than would be representative of natural site conditions (e.g., leaching due to rainwater infiltration). As a result, the TCLP results are conservative since they overestimate leachability relative to actual site conditions. The TCLP TPH and PAH results are summarized in Table VI-3.

Leachable total petroleum hydrocarbons (TPH), under the rigorous TCLP procedure, were not detected in samples with TPH concentrations up to 11,000 mg/kg. The only detected leachable TPH (16 mg/L) of the nine samples tested occurred in the sample containing the highest TPH

concentration of 19,000 mg/kg. No leachable cPAHs were detected in the Area 8 soil sample containing 6,900 mg/kg TPH.

Literature-derived values for cPAH partition coefficients provide additional support that residual hydrocarbon concentrations at the Site are protective of groundwater. Table VI-4 provides literature values for $\log K_{oc}$ (normalized organic carbon partition coefficient) for the cPAH compounds and an average measured organic carbon content for Site soils (fractional organic carbon content, f_{oc}). The soil:water partition coefficients (K_d values) for cPAHs were estimated by the expression $K_d = K_{oc} \times f_{oc}$. The estimated cPAH K_d values range from 9,600 to 1,205,000 (Table VI-4). Using the lowest estimated K_d value of 9,600 L/kg, a cPAH soil screening level for protection of groundwater (based on the conservative benzo(a)pyrene screening level) can be calculated as follows:

$$\begin{aligned}\text{Soil conc. (mg/kg)} &= \text{groundwater screening level (mg/L)} \times \\ &\quad K_d \text{ (L/kg)} \times \text{DAF} \\ &= (0.000012 \text{ mg/L}) (9,600 \text{ L/kg}) (100) \\ &= 12 \text{ mg/kg}\end{aligned}$$

As discussed in the lead cleanup summary, EPA determined during its development of the TCLP regulations (55 FR 11803) that a dilution/attenuation factor (DAF) of 100 is appropriate for the full range of constituents in the TCLP list, many of which are more mobile in the subsurface than cPAHs.

A total cPAH concentration of 12 mg/kg corresponds to a Bunker C-derived TPH concentration of 7,600 mg/kg (with 95% confidence; refer to Appendix V for TPH/cPAH regression analysis). This calculated TPH concentration is consistent with the fact that no leachable cPAHs were detected in a sample with 6,900 mg/kg Bunker C-derived TPH. This evaluation, with the TCLP data, supports 7,600 mg/kg TPH (Bunker C-derived) as protective of groundwater at the Site. All areas with Bunker C TPH sources have average concentrations (arithmetic mean and 95% UCL) below 7,600 mg/kg (refer to Tables I-1 and I-2 in Appendix I).

No areas of the Site have an average (arithmetic mean) cPAH concentration above 12 mg/kg. In fact, only two of 111 samples collected from the Site have detected cPAH concentrations above 12 mg/kg (one from Area 16 and one from Area 26). Because of the numbers of PAH samples and proportions of detections, the 95% UCL for cPAHs in these areas default to the maximum concentration according to MTCA statistical guidance (18 mg/kg in Area 16, and 37 mg/kg in Area 26; Table I-3 in Appendix I). Groundwater quality data from monitoring wells located immediately downgradient of Area 16 (MW-2, MW-3, and MW-5) and

Area 26 (MW-6) indicate no adverse impact to groundwater from TPH or cPAHs in these areas. Furthermore, cPAH results from samples collected below a depth of 1 foot in Area 16 (results provided in RI Deliverable I; Hart Crowser, 1992) indicate that the cPAHs, like the TPH, is limited to surficial soils impacted by Bunker C residue, i.e., there has been negligible vertical transport of cPAHs.

Although current MTCA guidance requires a single maximum sample result to represent average cPAH concentrations in Areas 16 and 26, all available data indicate that cPAHs in these areas, or in any area of the Site, do not pose a risk to groundwater or surface water.

Conclusions

Historical (pre-interim source removal) TPH and cPAH concentrations in soil have not adversely impacted groundwater or surface water at the Site. Evaluation of site-specific TCLP data and cPAH partition coefficients (K_d) supports a TPH concentration for Bunker C-derived petroleum concentrations of 7,600 mg/kg for protection of groundwater. Following interim source removal, no average concentrations of Bunker C-derived TPH are above 7,600 mg/kg. Furthermore, cPAH concentrations in soil do not pose a risk to groundwater or surface water. Therefore, remaining soils will not adversely impact groundwater or surface water quality at the Site in the future.

References for Appendix VI

Ecology, 1993. Washington State Department of Ecology Implementation Memo No. 3, PQLs as Cleanup Standards. Dated November 24, 1993.

Hart Crowser, 1992. RI Deliverable I, Remedial Investigation/Feasibility Study, Former DuPont Works Site, Dupont, Washington. October 7, 1992.

Montgomery & Welkom, 1991. Groundwater Chemical Desk Reference, Lewis Publishers, 1991.

tpb\TPH6.new

Attachments:

- Table VI-1 - Total Petroleum Hydrocarbon (TPH) Concentrations in mg/L in Groundwater and Surface Water
- Table VI-2 - Polycyclic Aromatic Hydrocarbon (PAH) Concentrations in mg/L in Groundwater and Surface Water
- Table VI-3 - Summary of Soil Petroleum Hydrocarbon Leachability Data
- Table VI-4 - Estimated Partition Coefficients (K_d) for cPAHs

tpH\TPH6.new

Table VI-1 - Total Petroleum Hydrocarbon (TPH) Concentrations in mg/L in Groundwater and Surface Water

Sheet 1 of 3

Sample ID	Location	TPH 418.1 in mg/L
Groundwater		
MW-1-12-92	MW-1	ND
MW-1-3-92	MW-1	ND
MW-1-6-92	MW-1	ND
MW-1-9-92	MW-1	ND
MW-2-12-92	MW-2	ND
MW-2-3-92	MW-2	ND
MW-2-6-92	MW-2	NDE
MW-2-9-92	MW-2	ND
MW-3-12-92	MW-3	ND
MW-3-3-92	MW-3	ND
MW-3-6-92	MW-3	NDE
MW-3-9-92	MW-3	ND
MW-4-12-92	MW-4	ND
MW-4-3-92	MW-4	ND
MW-4-6-92	MW-4	ND
MW-4-9-92	MW-4	ND
MW-5-12-92	MW-5	NDE
MW-5-3-92	MW-5	ND
MW-5-6-92	MW-5	ND
MW-5-9-92	MW-5	ND
MW-6-12-92	MW-6	ND
MW-6-3-92	MW-6	ND
MW-6-6-92	MW-6	ND
MW-6-9-92	MW-6	ND
MW-7-12-92	MW-7	ND
MW-7-3-92	MW-7	ND
MW-7-6-92	MW-7	NDE
MW-7-9-92	MW-7	ND
MW-8-12-92	MW-8	ND
MW-8-3-92	MW-8	ND
MW-8-6-92	MW-8	NDE
MW-8-9-92	MW-8	ND
MW-9-12-92	MW-9	ND
MW-9-3-92	MW-9	ND
MW-9-6-92	MW-9	NDE
MW-9-9-92	MW-9	ND
MW-11-12-92	MW-11	ND
MW-11-3-92	MW-11	ND
MW-11-6-92	MW-11	NDE
MW-11-9-92	MW-11	ND
MW-12-12-92	MW-12	ND
MW-12-3-92	MW-12	ND
MW-12-6-92	MW-12	NDE
MW-12-9-92	MW-12	ND
MW-13-12-92	MW-13	ND
MW-13-3-92	MW-13	ND
MW-13-6-92	MW-13	NDE
MW-13-9-92	MW-13	ND
MW-14-12-92	MW-14	ND
MW-14-3-92	MW-14	ND
MW-14-6-92	MW-14	ND

Table VI-1 - Total Petroleum Hydrocarbon (TPH) Concentrations in mg/L in Groundwater and Surface Water

Sheet 2 of 3

Sample ID	Location	TPH 418.1 in mg/L
MW-14-9-92	MW-14	ND
MW-15-1-93	MW-15	ND
MW-15-12-92	MW-15	ND
MW-15-3-92	MW-15	ND
MW-16-12-92	MW-16	ND
MW-16-3-92	MW-16	ND
MW-16-6-92	MW-16	NDE
MW-16-9-92	MW-16	ND
MW-17-12-92	MW-17	ND
MW-17-3-92	MW-17	ND
MW-17-6-92	MW-17	ND
MW-17-9-92	MW-17	ND
MW-18-12-92	MW-18	ND
MW-18-3-92	MW-18	ND
MW-18-6-92	MW-18	NDE
MW-18-9-92	MW-18	ND
MW-19-12-92	MW-19	ND
MW-19-3-92	MW-19	ND
MW-19-6-92	MW-19	NDE
MW-19-9-92	MW-19	ND
MW-20-12-92	MW-20	ND
MW-20-3-92	MW-20	ND
MW-20-6-92	MW-20	ND
MW-20-9-92	MW-20	ND
MW-21-12-92	MW-21	ND
MW-21-3-92	MW-21	ND
MW-21-6-92	MW-21	ND
MW-21-9-92	MW-21	ND
MW-22-12-92	MW-22	ND
MW-22-3-92	MW-22	ND
MW-22-6-92	MW-22	NDE
MW-22-9-92	MW-22	ND
MW-23-12-92	MW-23	ND
MW-23-3-92	MW-23	ND
MW-23-6-92	MW-23	NDE
MW-23-9-92	MW-23	ND
MW-24-12-92	MW-24	ND
MW-24-3-92	MW-24	ND
MW-24-6-92	MW-24	NDE
MW-24-9-92	MW-24	ND
MW-25-1-93	MW-25	ND
MW-25-12-92	MW-25	ND
MW-25-7-92	MW-25	ND
MW-25-9-92	MW-25	ND
MW-26-1-93	MW-26	ND
MW-26-12-92	MW-26	ND
MW-26-7-92	MW-26	ND
MW-26-9-92	MW-26	ND
MW-27-3-92	MW-27	ND
SEEP-1-12-92	SEEP-1	ND
SEEP-1-3-92	SEEP-1	ND
SEEP-1-6-92	SEEP-1	ND

Table VI-1 - Total Petroleum Hydrocarbon (TPH) Concentrations in mg/L in Groundwater and Surface Water

Sheet 3 of 3

Sample ID	Location	TPH 418.1 in mg/L
SEEP-1-9-92	SEEP-1	ND
SEEP-2-12-92	SEEP-2	ND
SEEP-2-3-92	SEEP-2	ND
SEEP-2-6-92	SEEP-2	ND
SEEP-2-9-92	SEEP-2	ND
SPR-3-12-92	SPR-3	ND
SPR-3-3-92	SPR-3	ND
SPR-3-9-92	SPR-3	ND
SPR-4-12-92	SPR-4	ND
SPR-4-3-92	SPR-4	ND
SPR-4-6-92	SPR-4	ND
SPR-4-9-92	SPR-4	ND
83-93-3-92	83-93	ND
83-94-3-92	83-94	ND
Surface Water		
SW-1-12-92	SW-1	ND
SW-1-3-92	SW-1	ND
SW-1-6-92	SW-1	ND
SW-2-12-92	SW-2	ND
SW-2-3-92	SW-2	ND
SW-2-6-92	SW-2	ND
SW-2-9-92	SW-2	ND
SW-3-12-92	SW-3	ND
SW-3-3-92	SW-3	ND
SW-3-6-92	SW-3	ND
SW-3-9-92	SW-3	ND
SW-4-3-92	SW-4	ND
SW-4-6-92	SW-4	ND
SW-5-12-92	SW-5	ND
SW-5-3-92	SW-5	ND
SW-5-6-92	SW-5	ND
SW-5-9-92	SW-5	ND
SW-6-12-92	SW-6	ND
SW-6-3-92	SW-6	ND
SW-6-6-92	SW-6	ND
SW-6-9-92	SW-6	ND
SW-7-12-92	SW-7	ND
SW-7-3-92	SW-7	ND
SW-7-6-92	SW-7	ND
SW-7-9-92	SW-7	ND

Notes:

ND Not detected at detection limit of 1 mg/L.

NDE Not detected at estimated detection limit of 1 mg/L.

Sample MW-5-12-92 not detected at estimated detection limit of 3 mg/L.

Table VI-2 - Polycyclic Aromatic Hydrocarbon (PAH) Concentrations in mg/L in Groundwater and Surface Water

Sample ID	Benzo(a)- Anthracene	Benzo(e)- Pyrene	Benzo(b)- Fluoran- thene	Benzo(k)- Fluoran- thene	Chrysene	Dibenz(a,h) Anthra- cene	Indeno- (1,2,3-c,d)- Pyrene	Total cPAHs (a)
Groundwater								
7-B-503	NDE	NDE	NDE	NDE	NDE	NDE	NDE	
MW-1-12-92	ND	ND	ND	ND	ND	ND	ND	
MW-1-3-92	ND	ND	ND	ND	ND	0.000015	ND	0.000015
MW-1-6-92	ND	ND	ND	ND	ND	ND	ND	
MW-1-9-92	ND	ND	ND	ND	0.0001	ND	ND	0.0001
MW-2-12-92	ND	ND	ND	ND	ND	ND	ND	
MW-2-3-92	ND	ND	ND	ND	ND	ND	ND	
MW-2-6-92	ND	ND	ND	ND	ND	ND	ND	
MW-2-9-92	NDE	NDE	NDE	NDE	NDE	NDE	NDE	
MW-3-12-92	ND	ND	ND	ND	ND	ND	ND	
MW-3-3-92	ND	ND	0.000025	ND	ND	ND	ND	0.000025
MW-3-6-92	ND	ND	ND	ND	ND	ND	ND	
MW-3-9-92	ND	ND	0.00001	ND	ND	ND	ND	0.00001
MW-4-12-92	ND	ND	ND	ND	ND	ND	ND	
MW-4-3-92	ND	ND	ND	ND	ND	ND	ND	
MW-4-6-92	ND	ND	ND	ND	0.00002	ND	ND	0.00002
MW-4-9-92	ND	ND	ND	ND	ND	ND	ND	
MW-5-12-92	ND	ND	ND	ND	ND	ND	ND	
MW-5-3-92	ND	ND	ND	ND	ND	ND	ND	
MW-5-6-92	ND	ND	ND	ND	ND	ND	ND	
MW-5-9-92	ND	ND	ND	ND	0.00003	ND	ND	0.00003
MW-6-12-92	ND	ND	ND	ND	ND	ND	ND	
MW-6-3-92	ND	ND	ND	ND	ND	ND	ND	
MW-6-6-92	ND	ND	ND	ND	ND	ND	ND	
MW-6-9-92	ND	ND	ND	ND	ND	ND	ND	
MW-7-12-92	ND	ND	ND	ND	ND	ND	ND	
MW-7-3-92	ND	ND	ND	ND	ND	ND	ND	
MW-7-6-92	ND	ND	ND	ND	ND	ND	ND	
MW-7-9-92	ND	ND	ND	ND	0.00001 J	ND	ND	0.00001
MW-8-12-92	ND	ND	ND	ND	ND	ND	ND	
MW-8-3-92	ND	ND	ND	ND	ND	ND	ND	

Table VI-2 - Polycyclic Aromatic Hydrocarbon (PAH) Concentrations in mg/L in Groundwater and Surface Water

Sample ID	Benzo(a)- Anthracene	Benzo(a)- Pyrene	Benzo(b)- Fluoranthene	Benzo(k)- Fluoranthene	Chrysene	Dibenzo- (a,h)Anthra- cene	Indeno- (1,2,3-c,d)- Pyrene	Total cPAHs (a)
MW-8-6-92	ND	ND	ND	ND	ND	ND	ND	
MW-8-9-92	0.00016	0.00008	0.00028	0.00025	0.00045	ND	0.00034	0.00156
MW-9-12-92	ND	ND	ND	ND	ND	ND	ND	
MW-9-3-92	ND	ND	ND	ND	ND	ND	ND	
MW-9-6-92	ND	ND	ND	ND	ND	ND	ND	
MW-9-9-92	ND	ND	ND	ND	ND	ND	ND	
MW-11-12-92	ND	ND	ND	ND	ND	ND	ND	
MW-11-3-92	ND	ND	ND	ND	ND	ND	ND	
MW-11-6-92	ND	ND	ND	ND	ND	ND	ND	
MW-11-9-92	ND	ND	ND	ND	ND	ND	ND	
MW-12-12-92	ND	ND	ND	ND	ND	ND	ND	
MW-12-3-92	ND	ND	ND	ND	ND	ND	ND	
MW-12-6-92	ND	ND	ND	ND	ND	ND	ND	
MW-12-9-92	ND	ND	ND	ND	0.00002	ND	ND	0.00002
MW-13-12-92	ND	ND	ND	ND	ND	ND	ND	
MW-13-3-92	ND	ND	ND	ND	ND	ND	ND	
MW-13-6-92	ND	ND	ND	ND	ND	ND	ND	
MW-13-9-92	ND	ND	ND	ND	ND	ND	ND	
MW-14-12-92	ND	ND	ND	ND	ND	ND	ND	
MW-14-3-92	ND	ND	ND	ND	ND	ND	ND	
MW-14-6-92	ND	ND	ND	ND	0.00002	ND	ND	0.00002
MW-14-9-92	ND	ND	ND	ND	ND	ND	ND	
MW-15-1-93	ND	ND	ND	ND	0.00003	ND	ND	0.00003
MW-15-12-92	NDE	NDE	NDE	NDE	NDE	NDE	NDE	
MW-15-3-92	ND	ND	ND	ND	ND	NDE	ND	
MW-15-7-92	NDE	NDE	NDE	NDE	NDE	NDE	NDE	
MW-16-12-92	ND	ND	ND	ND	ND	ND	ND	
MW-16-3-92	ND	ND	ND	ND	ND	ND	ND	
MW-16-6-92	ND	ND	ND	ND	ND	ND	ND	
MW-16-9-92	ND	ND	ND	ND	0.00002	ND	ND	0.00002
MW-17-12-92	ND	ND	ND	ND	0.00004	ND	ND	0.00004
MW-17-3-92	ND	ND	ND	ND	ND	ND	ND	

Table VI-2 - Polycyclic Aromatic Hydrocarbon (PAH) Concentrations in mg/L in Groundwater and Surface Water

Sample ID	Benzo(a)- Anthracene	Benzo(a)- Pyrene	Benzo(b)- Fluoranthene	Benzo(k)- Fluoranthene	Chrysene	Dibenzo- (a,h) Anthracene	Indeno- (1,2,3-c,d)- Pyrene	Total cPAHs (a)
MW-17-6-92	ND	ND	ND	ND	ND	ND	ND	
MW-17-9-92	ND	ND	ND	ND	ND	ND	ND	
MW-18-12-92	ND	ND	ND	ND	0.00007	ND	ND	0.00007
MW-18-3-92	ND	ND	ND	ND	ND	ND	ND	
MW-18-6-92	ND	ND	ND	ND	ND	ND	ND	
MW-18-9-92	NDE	NDE	NDE	NDE	NDE	NDE	NDE	
MW-19-12-92	ND	ND	ND	ND	ND	ND	ND	
MW-19-3-92	ND	ND	ND	ND	ND	ND	ND	
MW-19-6-92	ND	ND	ND	ND	0.00002	ND	ND	0.00002
MW-19-9-92	ND	ND	ND	ND	0.00001	ND	ND	0.00001
MW-20-12-92	ND	ND	ND	ND	ND	ND	ND	
MW-20-3-92	ND	ND	ND	ND	ND	ND	ND	
MW-20-6-92	ND	ND	ND	ND	ND	ND	ND	
MW-20-9-92	ND	ND	ND	ND	ND	ND	ND	
MW-21-12-92	ND	ND	ND	ND	ND	ND	ND	
MW-21-3-92	ND	ND	ND	ND	ND	ND	ND	
MW-21-6-92	ND	ND	ND	ND	0.00001	ND	ND	0.00001
MW-21-9-92	ND	ND	ND	ND	ND	ND	ND	
MW-22-12-92	ND	ND	ND	ND	ND	ND	ND	
MW-22-3-92	ND	ND	ND	ND	ND	ND	ND	
MW-22-6-92	ND	ND	ND	ND	ND	ND	ND	
MW-22-9-92	ND	ND	ND	ND	0.00001	ND	ND	0.00001
MW-23-12-92	ND	ND	ND	ND	ND	ND	ND	
MW-23-3-92	ND	ND	ND	ND	ND	ND	ND	
MW-23-6-92	ND	ND	ND	ND	ND	ND	ND	
MW-23-9-92	ND	ND	ND	ND	ND	ND	ND	
MW-24-12-92	ND	ND	ND	ND	ND	ND	ND	
MW-24-3-92	ND	ND	ND	ND	ND	ND	ND	
MW-24-6-92	ND	ND	ND	ND	ND	ND	ND	
MW-24-9-92	ND	ND	ND	ND	ND	ND	ND	
MW-25-1-93	NDE	NDE	NDE	NDE	NDE	NDE	NDE	
MW-25-12-92	ND	ND	ND	ND	ND	ND	ND	

Table VI-2 - Polycyclic Aromatic Hydrocarbon (PAH) Concentrations in mg/L in Groundwater and Surface Water

Sample ID	Benzo(a)- Anthracene	Benzo(a)- Pyrene	Benzo(b)- Fluoranthene	Benzo(k)- Fluoranthene	Chrysene	Dibenzo- (a,h)Anthracene	Indeno- (1,2,3-c,d)- Pyrene	Total cPAHs (a)
MW-25-7-92	ND	ND	ND	ND	ND	ND	ND	
MW-25-9-92	ND	ND	ND	ND	ND	ND	ND	
MW-26-1-93	ND	ND	ND	ND	0.00002	ND	ND	0.00002
MW-26-12-92	ND	ND	ND	ND	ND	ND	ND	
MW-26-7-92	ND	ND	ND	ND	ND	ND	ND	
MW-26-9-92	ND	ND	ND	ND	ND	ND	ND	
MW-27-3-92	ND	ND	ND	ND	ND	ND	ND	
SEEP-1-12-92	ND	ND	ND	ND	ND	ND	ND	
SEEP-1-3-92	ND	ND	ND	ND	ND	ND	ND	
SEEP-1-6-92	ND	ND	ND	ND	ND	ND	ND	
SEEP-1-9-92	ND	ND	ND	ND	ND	ND	ND	
SEEP-2-12-92	ND	ND	ND	ND	ND	ND	ND	
SEEP-2-3-92	ND	ND	ND	ND	ND	ND	ND	
SEEP-2-6-92	ND	ND	ND	ND	ND	ND	ND	
SEEP-2-9-92	ND	ND	ND	ND	ND	ND	ND	
SPR-3-12-92	ND	ND	ND	ND	ND	ND	ND	
SPR-3-3-92	ND	ND	ND	ND	ND	ND	ND	
SPR-3-9-92	ND	ND	ND	ND	ND	ND	ND	
SPR-4-12-92	ND	ND	ND	ND	ND	ND	ND	
SPR-4-3-92	ND	ND	ND	ND	ND	ND	ND	
SPR-4-6-92	ND	ND	ND	ND	ND	ND	ND	
SPR-4-9-92	ND	ND	ND	ND	ND	ND	ND	

Table VI-2 - Polycyclic Aromatic Hydrocarbon (PAH) Concentrations in mg/L in Groundwater and Surface Water

Sample ID	Benzo(a)- Anthracene	Benzo(a)- Pyrene	Benzo(b)- Fluoranthene	Benzo(k)- Fluoranthene	Chrysene	Dibenzo- (a,h)Anthra- cene	Indeno- (1,2,3-c,d)- Pyrene	Total cPAHs (a)
Surface Water								
SW-1-12-92	0.00009	0.00009	0.00017	0.00006 J	0.00023	ND	0.00007	0.00071
SW-1-3-92	ND	ND	ND	ND	ND	ND	ND	
SW-1-6-92	ND	ND	ND	ND	ND	ND	ND	
SW-2-12-92	ND	ND	ND	ND	ND	ND	ND	
SW-2-3-92	ND	ND	ND	ND	ND	ND	ND	
SW-2-6-92	ND	ND	ND	ND	ND	ND	ND	
SW-2-9-92	ND	ND	ND	ND	ND	ND	ND	
SW-3-12-92	ND	ND	ND	ND	ND	ND	ND	
SW-3-3-92	ND	ND	ND	ND	ND	ND	ND	
SW-3-6-92	ND	ND	ND	ND	ND	ND	ND	
SW-3-9-92	ND	ND	ND	ND	ND	ND	ND	
SW-4-3-92	ND	ND	ND	ND	ND	ND	ND	
SW-4-6-92	ND	ND	ND	ND	ND	ND	ND	
SW-5-12-92	ND	ND	ND	ND	ND	ND	ND	
SW-5-3-92	ND	ND	ND	ND	ND	ND	ND	
SW-5-6-92	ND	ND	ND	ND	ND	ND	ND	
SW-5-9-92	ND	ND	ND	ND	ND	ND	ND	
SW-6-12-92	ND	ND	ND	ND	ND	ND	ND	
SW-6-3-92	ND	ND	ND	ND	ND	ND	ND	
SW-6-6-92	ND	ND	ND	ND	ND	ND	ND	
SW-6-9-92	ND	ND	ND	ND	ND	ND	ND	
SW-7-12-92	ND	ND	ND	ND	ND	ND	ND	
SW-7-3-92	ND	ND	ND	ND	ND	ND	ND	
SW-7-6-92	ND	ND	ND	ND	ND	ND	ND	
SW-7-9-92	ND	ND	ND	ND	ND	ND	ND	

Notes: ND Not detected (cPAH detection limits ranging from 0.00001 to 0.00005 mg/L;
ncPAH detection limits ranging from 0.00001 to 0.00002 mg/L).
NDE Not detected (estimated cPAH detection limits ranging from 0.00001 to 0.00005 mg/L;
estimated ncPAH detection limits ranging from 0.00001 to 0.00002 mg/L).
J Estimated value.
(a) Total represents the sum of detected values only.

Table VI-2 - Polycyclic Aromatic Hydrocarbons (PAH) Concentrations in mg/L in Groundwater and Surface Water

Sample ID	Acenaph- thene	Acenaph- thylene	Anthra- cene	Benzo (g,h,i) Perylene	Fluoran- thene	Fluorene	Naph- thalene	Phenan- threne	Pyrene	Total ncPAHs (a)
Groundwater										
7-B-503	NDE	NDE	NDE	0.00006 J	NDE	NDE	NDE	0.00031 J	NDE	0.00037
MW-1-12-92	ND	ND	ND	ND	ND	ND	ND	0.00003	ND	0.00003
MW-1-3-92	ND	ND	ND	ND	ND	ND	ND	ND	ND	
MW-1-6-92	ND	ND	ND	ND	ND	ND	ND	ND	ND	
MW-1-9-92	ND	ND	0.00006	ND	ND	0.0011	0.0016	0.00041	ND	0.00317
MW-2-12-92	ND	ND	ND	ND	ND	ND	ND	ND	ND	
MW-2-3-92	ND	ND	ND	ND	ND	ND	ND	ND	ND	
MW-2-6-92	ND	ND	ND	ND	ND	ND	ND	ND	ND	
MW-2-9-92	NDE	NDE	NDE	NDE	NDE	NDE	NDE	NDE	NDE	
MW-3-12-92	ND	ND	ND	ND	ND	ND	ND	ND	ND	
MW-3-3-92	ND	ND	ND	ND	ND	ND	ND	0.00002	ND	0.00002
MW-3-6-92	ND	ND	ND	ND	ND	ND	ND	ND	ND	
MW-3-9-92	ND	ND	ND	ND	ND	ND	ND	0.00003	ND	0.00003
MW-4-12-92	ND	ND	ND	ND	ND	ND	ND	ND	ND	
MW-4-3-92	ND	ND	ND	ND	ND	ND	ND	ND	ND	
MW-4-6-92	ND	ND	ND	ND	ND	ND	ND	ND	ND	
MW-4-9-92	ND	ND	ND	ND	ND	ND	ND	ND	ND	
MW-5-12-92	ND	ND	ND	ND	ND	ND	ND	0.00004	ND	0.00004
MW-5-3-92	ND	ND	ND	ND	ND	ND	ND	0.000015	ND	0.000015
MW-5-6-92	ND	ND	ND	ND	ND	ND	ND	ND	ND	
MW-5-9-92	ND	ND	ND	ND	ND	ND	0.00033	0.00013	ND	0.00046
MW-6-12-92	ND	ND	ND	ND	ND	ND	ND	0.00004	ND	0.00004
MW-6-3-92	ND	ND	ND	ND	ND	ND	ND	ND	ND	
MW-6-6-92	ND	ND	ND	ND	ND	ND	ND	0.00003	ND	0.00003
MW-6-9-92	ND	ND	ND	ND	ND	ND	ND	ND	ND	
MW-7-12-92	ND	ND	ND	ND	ND	ND	ND	0.00004	ND	0.00004
MW-7-3-92	ND	ND	ND	ND	ND	ND	ND	ND	ND	
MW-7-6-92	ND	ND	ND	ND	ND	ND	ND	ND	ND	
MW-7-9-92	ND	ND	ND	ND	ND	ND	ND	ND	ND	
MW-8-12-92	ND	ND	ND	ND	ND	ND	ND	0.00005	ND	0.00005
MW-8-3-92	ND	ND	ND	ND	ND	ND	ND	0.000015	ND	0.000015

Table VI-2 - Polycyclic Aromatic Hydrocarbon (PAH) Concentrations in mg/L in Groundwater and Surface Water

[illegible]

Table VI-2 - Polycyclic Aromatic Hydrocarbon (PAH) Concentrations in mg/L in Groundwater and Surface Water

Sample ID	Acenaph- thene	Acenaph- thylene	Anthra- cene	Benzo (g,h,i) Perylene	Fluoran- thene	Fluorene	Naph- thalene	Phenan- threne	Pyrene	Total ncPAHs (a)
MW-17-6-92	ND	ND	ND	ND	ND	ND	ND	ND	ND	
MW-17-9-92	ND	ND	ND	ND	ND	ND	ND	ND	ND	
MW-18-12-92	ND	ND	ND	ND	0.00004	ND	ND	0.00009	ND	0.00013
MW-18-3-92	ND	ND	ND	ND	ND	ND	ND	0.00002	ND	0.00002
MW-18-6-92	ND	ND	ND	ND	ND	ND	ND	0.00005	ND	0.00005
MW-18-9-92	NDE	NDE	NDE	NDE	NDE	NDE	NDE	NDE	NDE	
MW-19-12-92	ND	ND	ND	ND	ND	ND	ND	ND	ND	
MW-19-3-92	ND	ND	ND	ND	ND	ND	ND	ND	ND	
MW-19-6-92	ND	ND	ND	ND	ND	ND	ND	0.00004	ND	0.00004
MW-19-9-92	ND	ND	ND	ND	ND	ND	ND	ND	ND	
MW-20-12-92	ND	ND	ND	ND	ND	ND	ND	ND	ND	
MW-20-3-92	ND	ND	ND	ND	ND	ND	ND	0.000022	ND	0.000022
MW-20-6-92	ND	ND	ND	ND	ND	ND	ND	ND	ND	
MW-20-9-92	ND	ND	ND	ND	ND	ND	ND	ND	ND	
MW-21-12-92	ND	ND	ND	ND	ND	ND	ND	ND	ND	
MW-21-3-92	ND	ND	ND	ND	ND	ND	ND	ND	ND	
MW-21-6-92	ND	ND	ND	ND	ND	ND	ND	ND	ND	
MW-21-9-92	ND	ND	ND	ND	ND	ND	ND	0.00001	ND	0.00001
MW-22-12-92	ND	ND	ND	ND	ND	ND	ND	ND	ND	
MW-22-3-92	ND	ND	ND	ND	0.00007	ND	ND	0.000035	ND	0.000105
MW-22-6-92	ND	ND	ND	ND	ND	ND	ND	0.00002	ND	0.00002
MW-22-9-92	ND	ND	ND	ND	ND	ND	ND	ND	ND	
MW-23-12-92	ND	ND	ND	ND	ND	ND	ND	0.00005	ND	0.00005
MW-23-3-92	ND	ND	ND	ND	ND	ND	ND	ND	ND	
MW-23-6-92	ND	ND	ND	ND	ND	ND	ND	ND	ND	
MW-23-9-92	ND	ND	ND	ND	ND	ND	ND	ND	ND	
MW-24-12-92	ND	ND	ND	ND	ND	ND	ND	ND	ND	
MW-24-3-92	ND	ND	ND	ND	ND	ND	ND	0.00003	ND	0.00003
MW-24-6-92	ND	ND	ND	ND	ND	ND	ND	ND	ND	
MW-24-9-92	ND	ND	ND	ND	ND	ND	ND	ND	ND	
MW-25-1-93	NDE	NDE	NDE	NDE	NDE	NDE	NDE	0.00002 J	NDE	0.00002
MW-25-12-92	ND	ND	ND	ND	ND	ND	ND	0.00006	ND	0.00006

Table VI-2 - Polycyclic Aromatic Hydrocarbon (PAH) Concentrations in mg/L in Groundwater and Surface Water

[illegible]

Table VI-2 - Polycyclic Aromatic Hydrocarbon (PAH) Concentrations in mg/L in Groundwater and Surface Water

Sample ID	Acenaph- thene	Acenaph- thylene	Anthra- cene	Benzo (g,h,i) Perylene	Fluoran- thene	Fluorene	Naph- thalene	Phenan- threne	Pyrene	Total ncPAHs (a)
Surface Water										
SW-1-12-92	ND	ND	0.00003	0.00014	0.00038	ND	ND	ND	0.00016 J	0.00071
SW-1-3-92	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
SW-1-6-92	ND	ND	ND	ND	ND	ND	ND	0.00004	ND	0.00004
SW-2-12-92	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
SW-2-3-92	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
SW-2-6-92	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
SW-2-9-92	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
SW-3-12-92	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
SW-3-3-92	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
SW-3-6-92	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
SW-3-9-92	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
SW-4-3-92	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
SW-4-6-92	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
SW-5-12-92	ND	ND	ND	ND	ND	ND	ND	0.00005	ND	0.00005
SW-5-3-92	ND	ND	ND	ND	ND	ND	ND	0.00002	ND	0.00002
SW-5-6-92	ND	ND	ND	ND	ND	ND	ND	0.00004	ND	0.00004
SW-5-9-92	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
SW-6-12-92	ND	ND	ND	ND	ND	ND	ND	0.00005	ND	0.00005
SW-6-3-92	ND	ND	ND	ND	ND	ND	ND	0.000025	ND	0.000025
SW-6-6-92	ND	ND	ND	ND	ND	ND	ND	0.00002	ND	0.00002
SW-6-9-92	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
SW-7-12-92	ND	ND	ND	ND	ND	ND	ND	0.00003	ND	0.00003
SW-7-3-92	ND	ND	ND	ND	ND	ND	ND	0.00002	ND	0.00002
SW-7-6-92	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
SW-7-9-92	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND

Notes: ND Not detected (cPAH detection limits ranging from 0.00001 to 0.00005 mg/L);
NDE ncPAH detection limits ranging from 0.00001 to 0.00002 mg/L);
J Not detected (estimated cPAH detection limits ranging from 0.00001 to 0.00005 mg/L);
I estimated ncPAH detection limits ranging from 0.00001 to 0.00002 mg/L);
(a) Estimated value.
Total represents the sum of detected values only.

Table VI-3 - Summary of Soil Petroleum Hydrocarbon Leachability Data

Sheet 1 of 2

Sample ID:	8-VS-SC-224	8-VS-SC-112	8-VS-SC-152	8-VS-SC-170
Station No:	2+82	12+90	8+93	7+12
Sampling Date:	6/10/93	6/07/93	6/08/93	6/08/93 (3)
Sample Depth in Feet:	15	15	15	15
TPH 418.1 in mg/kg (ppm)	6,900 (2)	5,400	2,340 (1)	6,000 (2)
TCLP TPH 418.1 in mg/L (ppm)	ND	ND	ND	ND
TCLP cPAHs in mg/L (ppm)				
Benzo(a)anthracene	ND	NA	NA	NA
Benzo(a)pyrene	ND	NA	NA	NA
Benzo(b)fluoranthene	ND	NA	NA	NA
Benzo(k)fluoranthene	ND	NA	NA	NA
Chrysene	ND	NA	NA	NA
Dibenzo(a,h)anthracene	ND	NA	NA	NA
Indeno(1,2,3,c,d)pyrene	ND	NA	NA	NA
Total cPAHs (a)	ND	—	—	—
Total cPAHs (b)	0.004	—	—	—
TCLP ncPAHs in mg/L (ppm)				
Acenaphthene	ND	NA	NA	NA
Acenaphthylene	ND	NA	NA	NA
Anthracene	ND	NA	NA	NA
Benzo(g,h,i)perylene	ND	NA	NA	NA
Fluoranthene	ND	NA	NA	NA
Fluorene	ND	NA	NA	NA
Naphthalene	ND	NA	NA	NA
Phenanthrene	ND	NA	NA	NA
Pyrene	ND	NA	NA	NA
Total ncPAHs (b)	0.015	—	—	—

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Notes:

ND Not detected (cPAH detection limits ranging from 0.001 to 0.0021 mg/L; ncPAH detection limits ranging from 0.0005 to 0.005 mg/L; TCLP TPH 418.1 not detected at detection limit of 1 mg/L).

NA Not analyzed.

(a) Total represents the sum of detected values only.

(b) Total includes one-half the detection limit of non-detected compounds.

(1) TPH Screening in mg/kg dry weight.

(2) TPH Screening in mg/kg wet weight.

(3) Sample location was excavated during subsequent source removal.

Table VI-3 - Summary of Soil Petroleum Hydrocarbon Leachability Data

Sheet 2 of 2

Sample ID:	8-VS-SC-208	8-VS-SC-296A	8-VS-SC-297A	8-VS-59	8-VS-81
Station No:	3+73	10+74	6+88	2+00	10+74
Sampling Date:	6/09/93	7/12/93 (3)	7/12/93 (3)	7/12/93	7/28/93
Sample Depth in Feet:	15	15	15	15	20
TPH 418.1 in mg/kg (ppm)	819 (1)	19,000	9,500	7,200	11,000
TCLP TPH 418.1 in mg/L (ppm)	ND	16	ND	ND	ND
TCLP cPAHs in mg/L (ppm)					
Benzo(a)anthracene	NA	NA	NA	NA	NA
Benzo(a)pyrene	NA	NA	NA	NA	NA
Benzo(b)fluoranthene	NA	NA	NA	NA	NA
Benzo(k)fluoranthene	NA	NA	NA	NA	NA
Chrysene	NA	NA	NA	NA	NA
Dibenzo(a,h)anthracene	NA	NA	NA	NA	NA
Indeno(1,2,3,c,d)pyrene	NA	NA	NA	NA	NA
Total cPAHs (a)	—	—	—	—	—
Total cPAHs (b)	—	—	—	—	—
TCLP ncPAHs in mg/L (ppm)					
Acenaphthene	NA	NA	NA	NA	NA
Acenaphthylene	NA	NA	NA	NA	NA
Anthracene	NA	NA	NA	NA	NA
Benzo(g,h,i)perylene	NA	NA	NA	NA	NA
Fluoranthene	NA	NA	NA	NA	NA
Fluorene	NA	NA	NA	NA	NA
Naphthalene	NA	NA	NA	NA	NA
Phenanthrene	NA	NA	NA	NA	NA
Pyrene	NA	NA	NA	NA	NA
Total ncPAHs (b)	—	—	—	—	—

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Notes:

ND Not detected (cPAH detection limits ranging from 0.001 to 0.0021 mg/L; ncPAH detection limits ranging from 0.0005 to 0.005 mg/L; TCLP TPH 418.1 not detected at detection limit of 1 mg/L).

NA Not analyzed.

(a) Total represents the sum of detected values only.

(b) Total includes one-half the detection limit of non-detected compounds.

(1) TPH Screening in mg/kg dry weight.

(2) TPH Screening in mg/kg wet weight.

(3) Sample location was excavated during subsequent source removal.

Table VI-4 - Estimated Partition Coefficients (Kd) for cPAHs

cPAH Compound	log Koc (a)	Koc	Average foc (b)	Estimated Kd (c)
Chrysene	5.39	245,000	0.039	9,600
Benzo(b)fluoranthene	5.74	550,000	0.039	21,500
Benzo(a)anthracene	6.14	1,380,000	0.039	53,800
Dibenzo(a,h)anthracene	6.22	1,660,000	0.039	64,700
Benzo(a)pyrene	5.6 to 6.29	398,000 to 1,950,000	0.039	15,500 to 76,100
Benzo(k)fluoranthene	6.64	4,365,000	0.039	170,200
Ideno(1,2,3-cd)pyrene	7.49	30,903,000	0.039	1,205,200

Notes:

- (a) Literature data from Montgomery and Welkom, 1991.
- (b) Average fractional organic carbon value from large-volume soil samples used for treatability studies.
- (c) $K_d = K_{oc} * f_{oc}$

APPENDIX VII

POTENTIAL ECOLOGICAL RISK OF TPH/cPAH

A quantitative ecological risk assessment was performed to estimate the potential risk posed by TPH/cPAH in soils at the Site to ecological receptors.

cPAHs

The ecological risk assessment for cPAHs used conservative models to approximate plant and animal uptake of cPAHs to derive potential doses for indicator species and evaluate risk. These methods are briefly summarized below.

Soil total cPAH concentrations were used as model inputs, and different exposure scenarios were simulated using a weighted statistical model. Soil cPAH concentrations were first normalized to benzo(a)pyrene equivalents (Appendix IV). Exposure concentrations for smaller animals were determined by calculating the upper confidence limit on the arithmetic mean (95% UCL) for individual areas of concern. Exposure concentrations for higher trophic animals were modeled by calculating the area weighted average for normalized cPAHs from sections of the Former DuPont Works Site and from the Site as a whole. The 95% UCL was then calculated for each weighted average. The area weighted approach provides a quantitative method for estimating cPAH exposure from animal foraging behavior.

The indicator species selected for the risk assessment included the Townsend Vole, Blacktail Deer, Red Fox, Red-tailed Hawk, and the Mallard Duck. Tasca et al. (1989) developed equations and assumptions to estimate daily intake of food, water, and incidentally ingested soil. The Department of Agriculture (DOA, 1985) catalogued the ranges and behaviors of indicator species. Plant uptake factors were derived from algorithms developed by Travis and Arms (1988) using benzo(a)pyrene as the modeled compound.

Based on this approach, daily chemical intakes of cPAHs were calculated for individual indicator species. These daily chemical intakes were compared against a laboratory No Observable Adverse Effects Level (NOAEL) for benzo(a)pyrene reported by Neal and Rigdon (1967). A hazard quotient was calculated for each indicator species by dividing the daily cPAH uptake by the reported NOAEL.

Results of this risk assessment indicate that higher trophic mammals such as foxes and deer have hazard quotients less than 0.1 and therefore are not at risk of cPAH toxicity. Avian species have hazard quotients below 1.0, demonstrating that Site conditions do not impact these species. Finally, smaller animals were demonstrated not to have any potential risks associated with cPAHs. Hazard quotients for cPAHs in voles ranged from less than 0.1 to a maximum of 1.2 in Area 26. The assumed cPAH exposure concentration in soil at Area 26 was 37 mg/kg (Appendix I). The results of the ecological risk assessment indicate that cPAH concentrations in individual areas below approximately 30 mg/kg (37 mg/kg/1.2) are protective of ecological receptors at the Site. This level is greater than the acceptable range of human health based cleanup levels established for total cPAHs of 1.0 to 10.0 mg/kg; therefore, cleanup based on human health risk would also be protective of ecological receptors on the Site.

TPH

Bunker C fuels are the primary petroleum constituent on the Site. Limited toxicity data are available for Bunker C in mammalian species. Recognizing that the risk posed by Bunker C is largely attributable to its cPAH components, the risk to ecological receptors from exposure to Bunker C-derived TPH was evaluated based on normalized cPAH concentrations.

The results of the ecological risk assessment indicate that cPAH concentrations in individual areas below approximately 30 mg/kg are protective of ecological receptors at the Site. This level corresponds to a TPH concentration of 76,000 mg/kg based on the regression analysis of the combined Bunker C-impacted areas (Appendix V). This level is greater than the range of cleanup levels established for the Site of 3,100 and 27,000 mg/kg, and therefore cleanup based on human health risk would be protective of ecological receptors on the Site.

Conclusions

Results of the ecological risk assessment indicate that a cPAH concentration of 30 mg/kg would be protective of ecological receptors on the Site. This level corresponds to a TPH concentration of 76,000 mg/kg, much greater than the range of cleanup levels for the Site of 3,100 and 27,000 mg/kg based on human health risk. Therefore cleanup to these levels would also be protective of ecological receptors on Site.

References for Appendix VII

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